UNITED STATES DEPARTMENT OF AGRICULTURE

MISCELLANEOUS CIRCULAR No. 81

WASHINGTON, D. C. FEBRUARY, 1927

THE RELATIONS BETWEEN CROP YIELDS AND PRECIPITATION IN THE GREAT PLAINS AREA

By E. C. CHILCOTT, Senior Agriculturist, in Charge of Office of Dry-Land Agriculture, Bureau of Plant Industry

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INTRODUCTION

THE RELATIONS between crop yields and precipitation probably have been subjects of wonder and surmise ever since the dawn of civilization. A few facts and many fallacies have been inherited by the present generation. The following chronicle of facts and events bearing upon this subject is arranged so as to be readily understood by farmers who are interested in the agricultural possibilities and limitations of the Great Plains.

The annual crop yields are expressed in figures representing bushels per acre, and the annual precipitation in figures representing inches of rainfall. It therefore becomes necessary to use averages, percentages, deviations from the mean, and ratios in order to show the relations, if any, between the facts presented; but beyond this no mathematical formulas or coefficients are used. Even where such mathematical expressions are used, they are intended to convey general impressions only. No attempt is made to reach mathematical exactness in the conclusions as to the relations of these facts.

No efforts have been made to support or to refute any theories or preconceptions. We are now interested only in actual facts and their relations. No single fact or phenomenon has been omitted, minimized, or exaggerated for the purpose of making some theory appear more plausible or less so. On the contrary, an earnest effort has been made to present the facts as they appeared to the original observers who noted them in the field. The large number of these observers, their practical experience, and their intimate knowledge of the agricultural and meteorological conditions and problems of the region would seem to assure the reduction of the personal equation to the minimum.

The purpose will be to give the facts that have been established by the equivalent of 303 years of practical experience on 23 farms located at designated points in the Great Plains area (fig. 1), together with a detailed report of the climatic conditions that have prevailed on each of these farms during the entire period of these investigations.

The detailed descriptions, comments, and explanations given in connection with the reports on yields are based upon the field notes taken by the respective associate agronomists who were in charge of the investigations at each of the 23 stations during the entire period. The total number of such men who have had charge of these field investigations during the last 20 years is 66.[1]

[1] The members of the scientific staff of the Office of Dry-Land Agriculture who have participated in conducting these investigations in the field and in assembling the data in the Washington office are as follows: *Present staff.*—Washington, D. C.: E. C. Chilcott, J. M. Stephens, E. F. Chilcott, J. S. Cole. Mandan, N. Dak., Robert Wilson, J. T. Sarvis, W. P. Baird, J. C. Thysell, T. K. Killand. Dickinson: N. Dak.: L. Moomaw. Assinniboine, Mont.: G. W. Morgan. Moccasin, Mont.. A. Osenbrug. Huntley, Mont.: A. E. Seamans. Bellefourche, S. Dak.: O. R. Mathews. Ardmore, S. Dak.: F. L. Kelso, J. D. Kelso. Sheridan, Wyo.: R. S: Towle. Archer, Wyo.: A. L. Nelson. North Platte, Nebr.: L. L. Zook, H. E. Weakly. Akron, Colo.: J. F. Brandon. Colby, Kans.: B. F. Barnes. Hays, Kans.. A. L. Hallsted. Garden City, Kans.: E. H. Coles. Woodward, Okla.: L. F. Locke. Dalhart, Tex.: H. J. Clemmer. Tucumcari, N. Mex.: D. R. Burnham, Lawton, Okla.: W. M. Osborn. Big Spring, Tex.: F. E. Keating—29. *Resigned or transferred to other offices.*—Sylvester Balz, F. L. Kennard, J. E. Payne, L. E. Hazen, C. A. Jensen, H. R. Reed, W. O. Whitcomb, C. H. Plath, F. Knorr, R. W. Edwards, H. C. McKinstry, C. A. Burmeister, J. G. Lill, W. W. Burr, J. H. Jacobson, O. J. Grace, M. Pfaender, W. D. Griggs, J. E. Mundell, W. A. Peterson, H. G. Smith, L. N. Jensen, A. J. Ogaard, C. B. Brown, L. D. Willey, J. B. Kuska, C. H. Ruzicka, A. W. Schulz, W. E. Lyness, F. A. Wagner, F. E. Cobb, P. V. Cardon, N. O. Henchel, J. W. McLane, O. A. Thompson, Clarence Harris, and U. G. Downey—37. Total, 66.

The field investigations at Assinniboine and Moccasin, Mont.; Williston, Dickinson, and Edgeley, N. Dak.; Archer, Wyo.; North Platte, Nebr.; Colby and Hays Kans.; and Tucumcari, N. Mex., herein described, were conducted cooperatively at field stations operated by the agricultural experiment stations of the several States, respectively.

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It is believed that the investigations which have been conducted on the Great Plains by the Office of Dry-Land Agriculture during the last 20 years furnish data having a direct bearing upon the problems involved in determining the relations between crop yields and precipitation such as can not be obtained at the present time from any other source.

There are certain conditions surrounding the investigation of these problems that have been met in order to provide a sound basis for safe conclusions, such as heretofore have never been provided; among these are the following:

(1) The investigations have been conducted in a semiarid region where there is no permanent water table near the surface and on land nearly level, but with sufficient slope for good surface drainage.

(2) The crops have been grown under natural field conditions, subject to all the hazards to which the farmer's crop is subject.

(3) The climatic data have been gathered on the same farm upon which the crops were grown.

(4) The investigations include a sufficient range of crops, soils, climatic seasons, tillage methods, and crop sequences to reduce to the minimum the effects of accidental combinations of factors that might seriously impair the value of the results obtained.

(5) The varieties and strains of crops used were well adapted to local conditions of soil and climate.

(6) Both the crop and the meteorological observations have been under the immediate personal supervision of a trained scientific agronomist who has noted and recorded at the time and on the spot every fact and incident that occurred, from the beginning of one crop year to the beginning of the next, that could reasonably be expected to influence the crop yield or in any way modify the effects of climatic or soil conditions.

(7) All of the data gathered by the scientists in immediate charge of the field investigations have been assembled, checked, compared, analyzed, interpreted, and recorded by experienced investigators, who have as complete knowledge of the investigations and of the conditions throughout the entire Great Plains area as the field investigators have of their respective local problems and conditions.

Table 1 shows the locations of the 23 field stations at which the investigations have been conducted, together with condensed information as to length of periods and number of plats used at each station.

FIG. 1.—Sketch map of the Great Plains area, which includes parts of 10 States and consists of about 450,000 square miles of territory. Its western boundary is indicated by the 5,000-foot contour. The location of each field station within the area is shown by a dot within a circle (⊙)

TABLE 1.—*List of field stations, showing the number of plats used for planting each crop at each station and the total number of plats upon which crop yields are based*

Field stations	Number of plats used for crops shown									Total plats	Years cropped	Total number of crops
	Crops for grain only						Kafir		Cotton, lint			
	Wheat											
	Winter	Spring	Oats	Barley	Corn	Milo	Grain	Total				
Williston, N. Dak.		19	21	5	19					64	12	768
Assiniboine, Mont.	32	30	58		48					168	9	1,512
Moccasin, Mont.	6	25	31		29					91	[1] 17	1,541
Huntley, Mont.	25	36	34		41					136	[2] 13	1,743
Dickinson, N. Dak.		25	27	5	23					80	18	1,440
Mandan, N. Dak.		67	66	22	60					215	11	2,365
Edgeley, N. Dak.		28	28	5	25					86	17	1,462
Sheridan, Wyo.	23	27	50		44					154	8	1,232
Bellefourche, S. Dak.	6	30	32		27					95	[3] 17	1,582
Ardmore, S. Dak.	12	39	41		42					134	12	1,608
Scottsbluff, Nebr.	11	27	37		36					111	10	1,110
North Platte, Nebr.	25	19	23	5	22					89	[4] 18	1,502
Archer, Wyo.	13	30	34		37					114	11	1,254
Akron, Colo.	17	23	31		27					98	16	1,568
Colby, Kans.	41			6	15	35				97	[5] 11	1,026
Hays, Kans.	40			15	21		26			102	18	1,836
Garden City, Kans.					17	13	23	23		53	16	848
Woodward, Okla.	20					25	32	32		77	10	770
Dalhart, Tex.					17	19	16	16		52	16	832
Tucumcari, N. Mex.					7	25	11	11		43	12	516
Amarillo, Tex.	15					12	10	10		37	13	481
Lawton, Okla.	26						33	33	27	86	9	774
Big Spring, Tex.						38	12	12	20	70	9	630
Total	312	435	513	63	557	167	[6] 163	[6] 137	47	2,252	303	28,400
Average (round numbers)	21	31	37	9	29	24	[6] 20	[6] 20	24	98	13	1,235

[1] Winter wheat, 16 years.
[2] Winter wheat, 12 years.
[3] Corn and winter wheat, 16 years.
[4] Winter wheat, 25 plats for 13 years; barley, 5 plats for 5 years.
[5] Barley and milo for only 10 years.
[6] The same plats of kafir were used for both grain and total.

It will be noted that the average length of time that these investigations have been conducted is approximately 13 years, ranging from 8 to 18 years and aggregating 303 years. The number of plats used at each station each year ranged from 37 to 215 and averaged 98 per station. The number of plats used at all stations each year was 2,252, and the number used at all stations for all years was 28,400, which is an average of 1,235 per station.

The average numbers of plats used at each station each year for determining the average yields for each crop were as follows: Winter wheat, 21; spring wheat, 31; oats, 37; barley, 10; corn, 29; milo, 24; kafir, 20; cotton, 24. In most cases the plats used at any given station differ from one another in some way as to methods of tillage or crop sequence. There are, however, some exact duplications.

In this connection no consideration will be given to the effects of tillage or crop sequence. These problems have been described in various other publications. Still more are in preparation and are to be published soon. In fact, the investigations herein recorded are considered the foundation for an intensive study of the results of crop rotations and tillage methods. If the yields from only the plats of highest production each year had been used, a much better showing would have been made of the agricultural possibilities of the region. On the other hand, if the lowest yields only had been used, the showing, obviously, would have been much lower. If the yields from each plat had been given, it would have made the problems of interpretation much more complex, and the conclusions in the end necessarily would have been based upon average yields from all plats.

It was therefore decided that only average yields should be used. Another reason for the use of averages is the fact that the crops grown in the immediate vicinity of the field stations by the better class of farmers have produced yields approximating, in a general way, those represented by our average yields, rather than by either our maximum or minimum yields.

Table 2 gives the monthly and annual means of precipitation for each of the 23 stations where these investigations were conducted.

TABLE 2.—*Monthly and annual average precipitation at 23 field stations in the Great Plains area*

[Arranged in the order of magnitude of the northern crop-year precipitation, stated in inches]

No.	Field stations	August	September	October	November	December	January	February	March	April	May	June	July	Annual
1	Lawton	2.08	2.12	5.03	1.43	0.89	1.23	0.62	1.86	3.47	4.12	2.91	2.75	28.51
2	Woodward	2.87	3.61	2.66	.93	.68	.88	.80	1.82	2.75	3.42	3.11	1.84	25.37
3	Hays	3.04	2.01	1.35	.84	.76	.28	.77	.77	2.28	3.36	3.60	2.53	21.59
4	Colby	2.48	1.86	1.22	.66	1.03	.34	.75	.85	2.30	2.70	2.56	3.54	20.29
5	North Platte	2.77	1.37	1.26	.66	.73	.38	.65	.84	1.91	3.11	3.15	3.19	20.02
6	Garden City	2.48	1.97	1.20	.75	.67	.33	.92	.88	1.97	2.48	2.80	2.56	19.01
7	Amarillo	3.05	2.25	1.47	.90	.81	.18	.73	.47	1.69	2.49	2.01	2.71	18.76
8	Tucumcari	2.72	1.78	1.87	.54	.76	.40	.35	.82	2.04	2.77	2.64	2.02	18.71
9	Dalhart	2.51	1.34	1.68	.54	.57	.25	.40	.81	2.04	3.12	3.19	2.23	18.68
10	Akron	2.14	1.58	1.13	.62	.82	.39	.55	.87	2.41	2.72	2.08	2.50	17.81
11	Big Spring	2.08	1.59	2.17	.82	.45	.50	.61	1.19	2.57	2.18	2.67	.97	17.80
12	Moccasin	1.68	1.66	1.25	.70	.74	.73	.62	.85	1.28	2.69	3.21	1.70	17.11
13	Edgeley	1.96	1.94	.85	.38	.30	.27	.30	.50	1.72	2.93	3.17	2.69	17.01
14	Ardmore	1.33	1.24	1.08	.45	.45	.31	.42	.57	2.28	3.25	3.10	2.21	16.69
15	Dickinson	2.01	1.37	.87	.48	.37	.37	.39	.64	1.21	2.28	3.49	2.57	16.05
16	Mandan	1.18	1.53	.75	.52	.43	.21	.34	.79	1.56	2.31	3.38	2.88	15.88
17	Bellefourche	1.46	1.60	1.10	.48	.53	.46	.43	.67	1.50	2.60	2.47	2.50	15.80
18	Scottsbluff	1.87	1.94	.90	.20	.47	.22	.33	.70	2.06	3.06	1.71	1.60	15.06
19	Archer	2.16	1.32	1.09	.59	.61	.21	.43	.54	2.12	2.21	1.81	1.72	14.81
20	Sheridan	.61	1.84	1.33	.68	.45	.69	.32	.88	1.80	2.39	2.29	1.51	14.79
21	Huntley	.89	1.57	1.21	.84	.81	.65	.38	.87	1.20	2.22	2.60	1.52	14.76
22	Williston	2.18	1.23	.86	.56	.54	.53	.33	.71	1.08	1.97	2.89	1.80	14.68
23	Assiniboine	.97	1.51	.60	.28	.50	.64	.36	.51	.87	1.52	2.80	1.80	12.36
	Mean	2.02	1.75	1.43	.65	.62	.45	.51	.84	1.92	2.69	2.77	2.23	17.89

These stations are here arranged in the order of the magnitude of the annual precipitation for the northern crop year, from August to July, inclusive. No distinction is made in this table between the stations which, in some of the tables which follow, are divided into northern and southern crop-year groups. The figures here given show the actual precipitation occurring each month for the northern crop year, whereas in some of the tables following the cumulative precipitation is shown.

THE CROP YEAR

For the purpose of this presentation it has seemed desirable to establish two different crop years, one for the North and one for the South. For the northern group of stations, 16 in number, the crop year begins August 1 and ends July 31 of the following calendar year. For the southern stations the crop year begins October 1 and ends September 30 of the following calendar year. The reasons for the selection of these periods for the crop years are that it is desirable to have the year begin as nearly as possible at the time when the principal crops mature and before the beginning of the preparation of the soil for the next crop. At the northern stations where spring wheat, winter wheat, and oats are the most important crops, this date is about August 1. At the southern stations, where the growing season is longer, October 1 is a better date, as many of the crops grown there do not mature until about that date.

By the adoption of crop years, as indicated, all the rain that falls after the harvesting of one crop is charged to the next crop, and tillage methods calculated to conserve the moisture can be adopted.

There are some exceptions to this general rule—as, for example, the corn crop in the northern Great Plains area does not mature until September, thus utilizing the rainfall of August and a portion of September of the following crop year. Winter wheat and early-sown spring crops on the southern Great Plains mature before the end of the crop year for that locality, thereby making it possible to begin moisture conservation operations during the latter part of one crop year for the benefit of the next year's crop. All of these facts are taken into consideration in adopting cropping systems and in estimating the relations between crop yields and precipitation.

Nevertheless, most of the staple crops grown throughout the Great Plains can be studied more satisfactorily by using the crop years, as indicated, respectively, for the northern and the southern portions, instead of the calendar year.

In Table 3 the same monthly and annual precipitations are used as in Table 2, but they are presented cumulatively.

The term "cumulative precipitation" is used in these pages to designate the total precipitation that has occurred in the interval between the beginning of the crop year and the close of each month during the crop year. The cumulative precipitation for the first month of the crop year is, of course, the precipitation for that month; for the second month it is the sum of the precipitation for the first and second months; for the third month it is the sum of the first, second, and third—and so on to the end of the year. The cumulative precipitation for the last month of the crop year is the same as the total precipitation for the crop year.

The stations are arranged in two groups, the southern and the northern. Within the respective groups the stations are arranged in the order of magnitude of the precipitation for the crop year; and the average annual yields for four of the leading crops for the respective localities are given on the same line following the precipitation.

TABLE 3.—*Average cumulative monthly precipitation and comparative crop yields at 23 field stations in the Great Plains area*

[Arranged in order of magnitude of yearly precipitation for two groups of crop years: Southern group, October to September, inclusive; northern group, August to July inclusive. Yields of four leading crops arranged in same order]

Field stations	Cumulative precipitation (inches)												Average acre yields									
													Wheat		Oats	Barley	Corn		Sorghum			Cotton, lint	Years averaged
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Winter	Spring			Grain	Total	Milo grain	Kafir Grain	Kafir Total		
Southern group:													*Bus.*	*Bus.*	*Bus.*	*Bus.*	*Bus.*	*Lbs.*	*Bus.*	*Bus.*	*Lbs.*	*Lbs.*	
Lawton	5.03	6.46	7.35	8.58	9.20	11.06	14.53	18.65	21.56	24.31	26.39	28.51	16.6							16.0	4,002	200	9
Woodward	2.66	3.59	4.27	5.15	5.95	7.77	10.52	13.94	17.05	18.89	21.76	25.37	16.6						19.2	20.8	5,140		10
Garden City	1.20	1.95	2.62	2.95	3.87	4.75	6.72	9.20	12.00	14.56	17.04	19.01					7.9		18.1	13.0	3,776		16
Amarillo	1.47	2.37	3.18	3.36	4.09	4.56	6.25	8.74	10.75	13.46	16.51	18.76	7.3						23.2	13.2	4,819		13
Tucumcari	1.87	2.41	3.17	3.57	3.92	4.74	6.78	9.55	12.19	14.21	16.93	18.71					16.6		25.7	18.7	3,668		12
Dalhart	1.68	2.22	2.79	3.04	3.44	4.25	6.29	9.41	12.60	14.83	17.34	18.68					13.4		23.1	19.1	5,819		16
Big Spring	2.17	2.99	3.44	3.94	4.55	5.74	8.31	10.49	13.16	14.13	16.21	17.80							22.2	15.6	3,562	206	9
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July											
Northern group:																							
Hays	3.04	5.05	6.40	7.24	8.00	8.28	9.05	9.82	12.10	15.46	19.06	21.59	18.2			19.9	6.1	2,883		19.0			18
Colby	2.48	4.34	5.56	6.22	7.25	7.59	8.34	9.19	11.49	14.19	16.75	20.29	19.2			22.6	20.9	3,308	16.5				11
North Platte	2.77	4.14	5.40	6.06	6.79	7.17	7.82	8.66	10.57	13.68	16.83	20.02	18.8	12.9	28.3	21.5	19.8	3,779					18
Akron	2.14	3.72	4.85	5.47	6.29	6.68	7.23	8.10	10.51	13.23	15.31	17.81	12.2	9.7	21.3		13.8	2,612					16
Moccasin	1.68	3.34	4.59	5.29	6.03	6.76	7.38	8.23	9.51	12.20	15.41	17.11	17.1	17.6	36.1			4,578					17
Edgeley	1.96	3.90	4.75	5.13	5.43	5.70	6.00	6.50	8.22	11.11	14.32	17.01		16.9	34.6	20.5		3,825					17
Ardmore	1.33	2.57	3.65	4.10	4.55	4.86	5.28	5.85	8.13	11.38	14.48	16.69	14.9	17.4	32.8		15.0	2,991					12
Dickinson	2.01	3.38	4.25	4.73	5.10	5.47	5.86	6.50	7.71	9.99	13.48	16.05		19.3	39.5	24.6	15.1	3,509					18
Mandan	1.18	2.71	3.46	3.98	4.41	4.62	4.96	5.75	7.31	9.62	13.00	15.88		17.1	40.3	21.8	29.0	4,264					11
Bellefourche	1.46	3.06	4.16	4.64	5.17	5.63	6.06	6.73	8.23	10.83	13.30	15.80	15.1	16.9	35.5		21.1	3,479					17
Scottsbluff	1.87	3.81	4.71	4.91	5.38	5.60	5.93	6.63	8.69	11.75	13.46	15.06	10.6	11.8	24.1		20.7	3,301					10
Archer	2.16	3.48	4.57	5.16	5.77	5.98	6.41	6.95	9.07	11.28	13.09	14.81	10.8	10.8	17.0		15.9	2,822					11
Sheridan	.61	2.45	3.78	4.46	4.91	5.60	5.92	6.80	8.60	10.99	13.28	14.79	21.8	17.0	36.5		18.6	2,979					8
Huntley	.89	2.46	3.67	4.51	5.32	5.97	6.35	7.22	8.42	10.64	13.24	14.76	23.0	16.4	34.9		20.6	3,313					13
Williston	2.18	3.41	4.27	4.83	5.37	5.90	6.23	6.94	8.02	9.99	12.88	14.68		16.1	35.0	21.0		4,282					12
Assiniboine	.97	2.48	3.08	3.36	3.86	4.50	4.86	5.37	6.24	7.76	10.56	12.36	8.6	13.6	26.0			2,763					9
Average												17.89	15.4	15.3	31.6	21.7	17.0	3,418	21.1	16.9	4,398	203	

The figures from which these summaries are derived are given in detail under "Comparisons of data presented at the several stations."

CROP YIELDS

It will be noted that "Kafir total" is given in pounds per acre as one of the leading crops grown at all of the southern stations and that "Corn total" is given for all of the northern stations. These crops are grown for silage, and the entire crop, both grain and stalks, is used. If sold for market prices on the farm, these crops would not prove profitable; but, as they fit into the rotations and provide feed for livestock, they have a value in the farming system far exceeding their market value if sold in the raw state. At most of the northern stations the yields of grain from the corn crop are sufficient to afford a standard of values for the crop in the general farming system. In such instances both the yields of shelled corn and the total weight of the crop are given.

TABLE 4.—*Average yields of wheat, oats, barley, corn, and sorghum in the Great Plains area, compared with those of other regions, from 1908 to 1920, inclusive*

Region covered	Average acre yields of grain (bushels)							
	Wheat		Oats	Barley	Corn	Sorghum		
	Spring wheat	Winter wheat				Milo	Kafir	Total
United States	12.8	15.6	31.6	24.9	26.5			20.4
Great Plains	15.3	15.4	31.6	21.7	17.0	21.1	16.9	19.0
Difference	2.5	−.2		−3.2	−9.5			−1.4

The Agricultural Yearbook, 1923 (pp. 605–606, 665, 682, 698, 729), gives the average yields of wheat, corn, oats, barley, and sorghum in the United States for the periods from 1908 to 1920, inclusive. In Table 4 these yields are compared with the yields of these crops in the Great Plains area.

From Table 4 it appears that the average yields of winter wheat as determined by these investigations were substantially the same as the Yearbook figures: For spring wheat, 2.5 bushels higher; for oats, the same; for barley, 3.2 bushels lower; for the grain sorghums (milo and kafir averaged 19 bushels), 1.4 bushels lower. The yields of corn have been relatively low, in fact only about two-thirds that of the United States as a whole. This is as would be expected, as no part of the Great Plains as represented by these investigations can be considered a corn country. Corn, however, is a profitable crop to grow to a certain extent in much of the northern portion of the area, as heretofore explained.

In this connection it must be borne in mind that the crop yields herein reported are the average yields obtained from a number of different methods of tillage and crop rotation, some of which are known to be inefficient, but which are used for the purpose of comparison with other more efficient methods. These investigations show that no one method always gives the best results at any individual station, the variations in climatic conditions from year to year making sometimes one and sometimes another the best of several different methods or rotations for that particular combination of soil and climatic conditions and crop requirements. Such being the case, it is practically impossible to make any definite mathematical calculation of just what average yields would have been obtained if only the best methods and rotations had been used each year at each station upon all the plats.

The agricultural hazards on the Great Plains are of a somewhat different character from those of more humid regions. At each one of the 23 stations there have been years when crop failure was practically complete. In some instances such years have occurred in unbroken succession for two or more years. Sometimes these failures have been due to insufficient annual precipitation, sometimes to hail, and sometimes to a combination of both. Inopportune distribution of precipitation is frequently the cause of serious crop losses. Plant diseases, insect pests, and weeds may also become important factors, although they are not usually as serious hazards here as in more humid regions. Soil blowing is an ever-present menace during the spring months. This danger is not confined to light, sandy soils as is sometimes assumed. In some instances it occurs with disastrous effects upon heavy clay soils, where the clay will be torn off in flakes from the surface of the soil and be carried along by the wind with the same results as those of sand particles on sandy soils.

Heavy winds occurring when the small-grain crops have reached or are approaching maturity sometimes do great damage by shattering the heads and breaking down the stems. Along the international boundary in North Dakota and Montana, and across the line in Canada, frost damage may occur, both in the spring and just before maturity of the crops in late August or in September. In Texas, Oklahoma, and New Mexico heavy rains sometimes occur in September, October, and November that make the curing of late-maturing crops of sorghums difficult and may result in serious loss to the crop after it has been grown and harvested. All these conditions and many others, some known and others unknown, may be included under the general term "inhibiting factors." This term will occur frequently in these pages and is always used to include all factors other than insufficient annual precipitation which tend to reduce crop yields below those that have been obtained at the same station in other years with no greater annual precipitation.

This is a rather formidable array of hazards to which crops in semiarid regions are subject, but it is probably no worse than those to which crops in humid regions are subject and possibly not so bad as they are. Nevertheless, the inhibiting factors must be recognized, for some of them undoubtedly are sufficiently potent in the growth of every crop to prevent the production of the yields that should be produced when the annual precipitation is normal or above.

It is customary to think of the number of inches of annual precipitation as the most important factor in determining the success or failure of crop production on the Great Plains. The fertility of the soil may be considered as a constant, as practically all soils in this region are sufficiently fertile to produce abundant crops if the climatic conditions are favorable.

These investigations seem to indicate that not only the seasonal and monthly but also the daily distribution of the precipitation may be much more important than its annual magnitude. They also raise the question as to whether the inhibiting factors already mentioned may not be of greater importance than either annual precipitation or soil fertility. This matter is given careful consideration in the text accompanying the diagrams.

Having enumerated in some detail the hazards of agriculture on the Great Plains, it is only fair to call attention to some of its advantages. Among these are the following: Land is relatively cheap. It is much more easily tilled than that of most of the humid regions. These two conditions combine to make possible a more extensive and a more economical system of crop production than can be conducted where land is high priced and relatively difficult to till. The climate of the entire Plains region is healthful and invigorating. The population, as a rule, is progressive and enterprising. School and cooperative social and business organizations thrive in the agricultural communities. Good roads and automobiles, the telephone, and the radio have practically eliminated the isolation of the farm home, which was so serious a menace to the happiness and culture of the early settlers in that region.

METHODS OF PRESENTATION OF RESULTS

As far as possible, the diagrams and tables which follow are self-explanatory, but attention is here called to the following features of this method of presentation. Diagrams showing in detail the relations between annual crop yields and precipitation by five-day, monthly, and crop-year periods are given for each of the 23 field stations, each detailed presentation being summarized graphically by a facing diagram in each instance. The presentations thus shown as a series in pairs are referred to as Figures 2 to 47, inclusive.

For the first 16 stations, representing the northern group, the crop year begins August 1 and continues to July 31 of the following calendar year. For the 7 southern stations the crop year begins on October 1 and ends September 30 of the following calendar year. The reasons for the selection of these periods have been explained under "The crop year." The precipitation is given in inches diagrammatically for each five-day period and in figures by months. The total precipitation for the crop year is given in inches in the first column at the right of the July and September columns, respectively, in the detailed presentations. The seasonal precipitation for the four growing months, April to July, inclusive, is given in Table 14 (p. 84) and is included in the graphic summary for each station. In the even-numbered figures of this series the two columns to the right of the one occupied by the figures for the annual precipitation for the crop years contain the names of the crops studied at each station and their respective yields per acre expressed in bushels or pounds per acre for the respective crops. The extreme right-hand column indicates the year when the crops were harvested, or the crop year. The figures in the extreme left-hand column indicate the calendar year of the fall and winter months included in the crop year. The two horizontal lines at the bottom of these even-numbered figures show, respectively, the name of the months and the average monthly precipitation for each month and the average annual precipitation for the period of years covered by these investigations at that station.

The odd-numbered figures of the series are so arranged that the upper portion of each is devoted primarily to crop yields and incidentally also to seasonal rainfall and evaporation, while the lower portion is devoted entirely to precipitation. The value assigned to each fine horizontal line is expressed on the scale at the left-hand side of each figure, indicating either inches or bushels, as the case may be. The perpendicular lines indicate crop years. The years are not arranged in chronological sequence, but in the order of magnitude of the annual precipitation for each year,

WILLISTON (N. DAK.) FIELD STATION

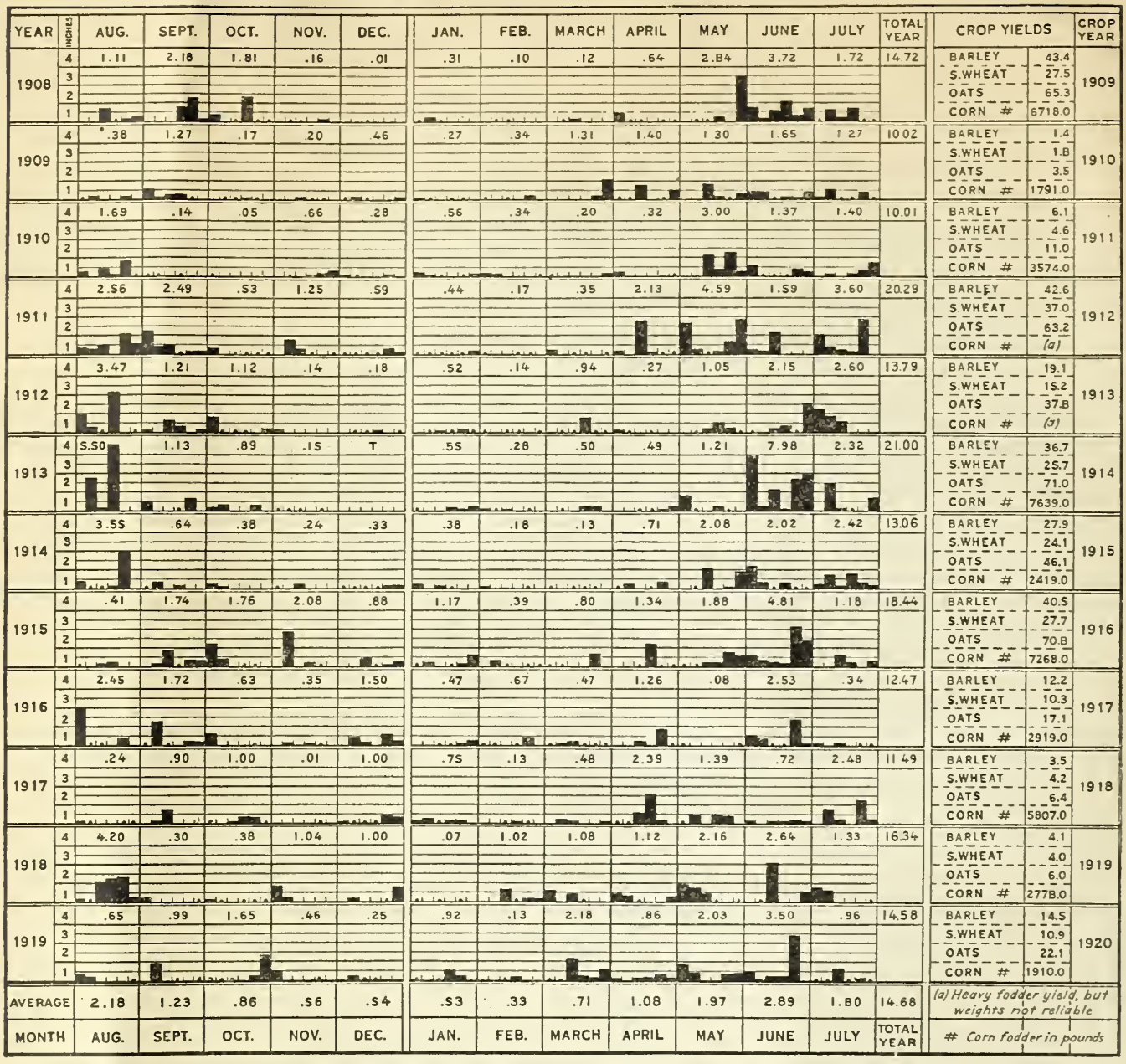


FIG. 2.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Williston (N. Dak.) Field Station

the wettest year at the left and the driest year at the right. Such an arrangement facilitates comparisons of the yields of crops grown during years having but slight differences in annual precipitations, which are arranged on adjacent perpendicular lines. It also permits the annual precipitation to be represented on a progressively descending line from left to right instead of on a broken line as would be the case if the years were arranged in chronological order. This regularly descending line is used as a datum line, or basis of comparison, with broken lines representing other factors, such as crop yields and monthly precipitation. The values of all precipitation and evaporation data, and of all crop yields, except those of oats, are read directly from the scale at the left of the figure. In the case of oats the yields shown on this scale should be doubled. This arrangement permits of a much more compact diagram and facilitates comparisons between oat and other grain yields. With this single exception, the upper portion of each figure treats values in conventional form.

The arrangement of the lower portion of the odd-numbered figures, dealing with precipitation, is easily understood. The first line above the base represents the cumulative precipitation of the fall group of months—August, September, October, and November. The second line represents the cumulative precipitation of the months of August to March, inclusive, and the width of the interval between it and the first line represents the cumulative precipitation of the winter months —December, January, February, and March. The third line represents the cumulative precipitation of the months August to April, inclusive, and the interval between it and the second line represents the April rainfall. The other three lines represent the cumulative precipitation from August 1 to May 31, June 30, and July 31, respectively. The intervals between them represent the monthly precipitation of each

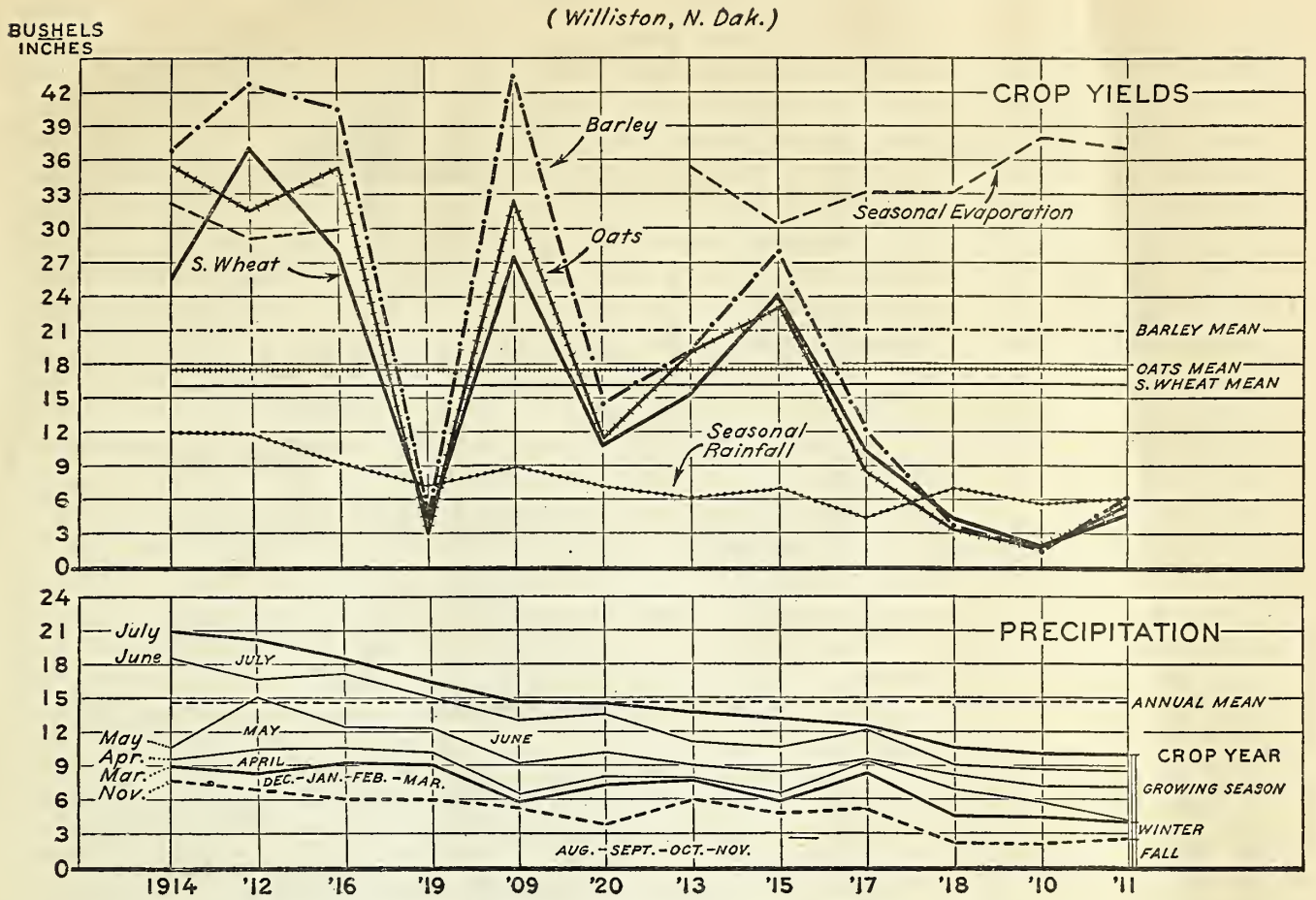


FIG. 3.—Diagram summarizing the relations between rainfall and crop yields at Williston, N. Dak. (See text, p. 9)

month, respectively. The upper line also represents the cumulative annual precipitation for the crop year.

The lines representing seasonal precipitation and evaporation are placed in the upper portion of the figure. It is thus made easy to note at a glance the relations between crop yields, annual precipitation, seasonal precipitation, and evaporation for any and all years, the years shown at the bottom being applicable to both the upper and lower portions of the figure.

Corn is an important crop on the northern Great Plains, when grown in rotation with wheat and oats. Yields of either the grain or the total weight of the corn crop, therefore, are given in the even-numbered diagrams, but they have been omitted from the odd-numbered diagrams. The reason for this omission is that corn is not so well adapted to these climatic conditions as are wheat and oats and is, therefore, of relatively little value for determining the relations between crop yields and annual precipitation, for which purpose the odd-numbered diagrams are especially designed.

COMPARISONS OF DATA PRESENTED AT THE SEVERAL STATIONS.

In connection with the presentation for each of the 23 field stations are given, for the period covered by these investigations, the means of the meteorological factors and of crop yields, the number of plats devoted to each crop, and the character of the soil at the station under consideration.

Each crop year is then considered in normal chronological order. Percentage deviations above or below means of annual precipitation, seasonal precipitation, and yields of each of the four crops are expressed in figures.

To facilitate comparisons of these factors they are expressed diagrammatically, the perpendicular line representing the respective means and the horizontal lines the deviations from the means in percentages of the respective means. Deviations from the means are represented by extensions, to the right for those above the mean and to the left for those below. The relative lengths of these extensions are proportional to the percentages of deviation. If directly proportional relations existed between the crop yields and the precipitations here represented, these extensions, if any, would be all in the same direction and to the same extent for any one year at any one station. That no such proportional relations exist between either seasonal or annual precipitation and crop yields is obvious from an examination of these diagrams. Still more conclusive are the facts that the mean percentage deviations for all of the 23 stations for the periods during which these investigations have been conducted, an aggregate of 303 years, are as follows:

Seasonal precipitation, from 69 above to 49 below, a range of 118 per cent; annual precipitation from 49 above to 38 below, a range of 87 per cent. For crop yields the deviations are from 171 above to 99 below, a range of 270 per cent, which is more than twice as great for crop yields as for seasonal precipitation and about three times as great as for annual precipitation.

It is a perfectly obvious fact that crop plants, like animals, must have water for life and growth. It is equally obvious that there must be a lower limit to the

ASSINNIBOINE (MONT.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1915	4	.94	2.05	.42	.12	.77	1.75	.47	.59	.69	2.69	4.32	5.20	20.01	W.WHEAT	38.6	1916
	3														S.WHEAT	49.1	
	2														OATS	92.2	
	1														CORN #	4437.0	
1916	4	.20	1.90	.82	.15	.58	.51	.20	.04	.86	.42	1.59	.43	7.70	W.WHEAT	7.2	1917
	3														S.WHEAT	6.4	
	2														OATS	10.4	
	1														CORN #	1040.0	
1917	4	.70	5.33	.38	.08	1.32	.75	.25	.40	.44	.08	1.51	.74	11.98	W.WHEAT	6.1	1918
	3														S.WHEAT	8.3	
	2														OATS	10.5	
	1														CORN #	2017.0	
1918	4	2.10	.64	1.17	.42	.05	.38	.56	.50	.31	1.09	1.99	.19	9.40	W.WHEAT	3.7	1919
	3														S.WHEAT	3.2	
	2														OATS	2.6	
	1														CORN #	452.0	
1919	4	.60	.67	.48	.56	.23	.88	.30	.40	1.71	1.39	2.20	1.36	10.78	W.WHEAT	4.6	1920
	3														S.WHEAT	10.8	
	2														OATS	22.8	
	1														CORN #	3198.0	
1920	4	1.26	.35	1.04	.01	.30	.05	.06	1.81	.80	2.83	2.68	2.16	13.35	W.WHEAT	7.2	1921
	3														S.WHEAT	10.1	
	2														OATS	23.7	
	1														CORN #	2858.0	
1921	4	.53	1.45	.19	.70	.11	.19	.76	.27	1.43	2.37	.90	1.90	10.80	W.WHEAT	6.0	1922
	3														S.WHEAT	4.7	
	2														OATS	11.0	
	1														CORN #	2697.0	
1922	4	.92	.54	.11	.31	.56	1.00	.15	.05	.78	1.93	4.86	3.65	14.86	W.WHEAT	0.0	1923
	3														S.WHEAT	18.2	
	2														OATS	28.8	
	1														CORN #	4486.0	
1923	4	1.49	.64	.73	.15	.60	.27	.49	.55	.82	.89	5.14	.61	12.38	W.WHEAT	4.1	1924
	3														S.WHEAT	11.2	
	2														OATS	32.1	
	1														CORN #	3681.0	
AVERAGE		.97	1.51	.60	.28	.50	.64	.36	.51	.87	1.52	2.80	1.80	12.36			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	# Corn fodder in pounds		

FIG. 4.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Assinniboine (Mont.) Field Station

water supply, below which neither plants nor animals can live, but this limit will vary widely between different plants and animals. It will also be subject to great variation due to environmental conditions, the presence of assimilable food, and many other factors.

Assuming that either a crop plant or an animal has available a sufficient supply of water to continue to exist and that this supply is gradually augmented above this minimum, then growth or energy may be developed, provided other environmental influences are sufficiently favorable. It is probable that with some plants and some animals, under favorable environmental conditions, there would come a stage in the gradual augmentation of the water supply when there would be a directly proportional relation between water supply and growth, or the development of energy; but, if so, it would be through a very narrowly limited range of increase in the water supply, and even within this narrow range it is probable that under all ordinary environmental conditions there would be inhibiting factors that would throw these proportional relations out of equilibrium.

The purpose of introducing the above facts to the reader at this point is to enable him correctly to interpret the facts that are herein presented concerning the relations between precipitation and crop yields; for, if he has the patience to study carefully these notes, comments, and comparisons of data covering 303 crop years, he will find his center of interest gradually shifting away from the rainfall data and centering upon considerations of the inhibiting factors other than deficient annual rainfall, which seem to be the major factors determining the crop yields.

When this stage is reached, the reader will find it easy to account for the very low yields sometimes obtained when rainfall seems to have been adequate for the production of a good crop by assuming that there was some inhibiting factor which was responsible for the decrease. But when, on the other hand, he finds very high yields reported when the rainfall is little if any above the mean, he may at first find difficulty in explaining the seemingly anomalous circumstance. He should, however, call to mind the fact that every inhibiting factor that has influenced the yield of any crop during the entire period of the investigation of that crop at that station has tended to lower the mean yield of that crop at that station. Therefore, when a year occurs when there are comparatively few inhibiting factors, or their potency is reduced, the yields may be two or three times the mean, as happened at Bellefourche and other stations in 1915. It is thus seen that inhibiting factors, by their relative impotence, may explain abnormally high yields. This subject is considered more fully elsewhere (p. 87).

It is probable that the notes of the field men, particularly in the earlier years, did not place sufficient emphasis upon inhibiting factors, as their real significance has dawned but slowly upon investigators.

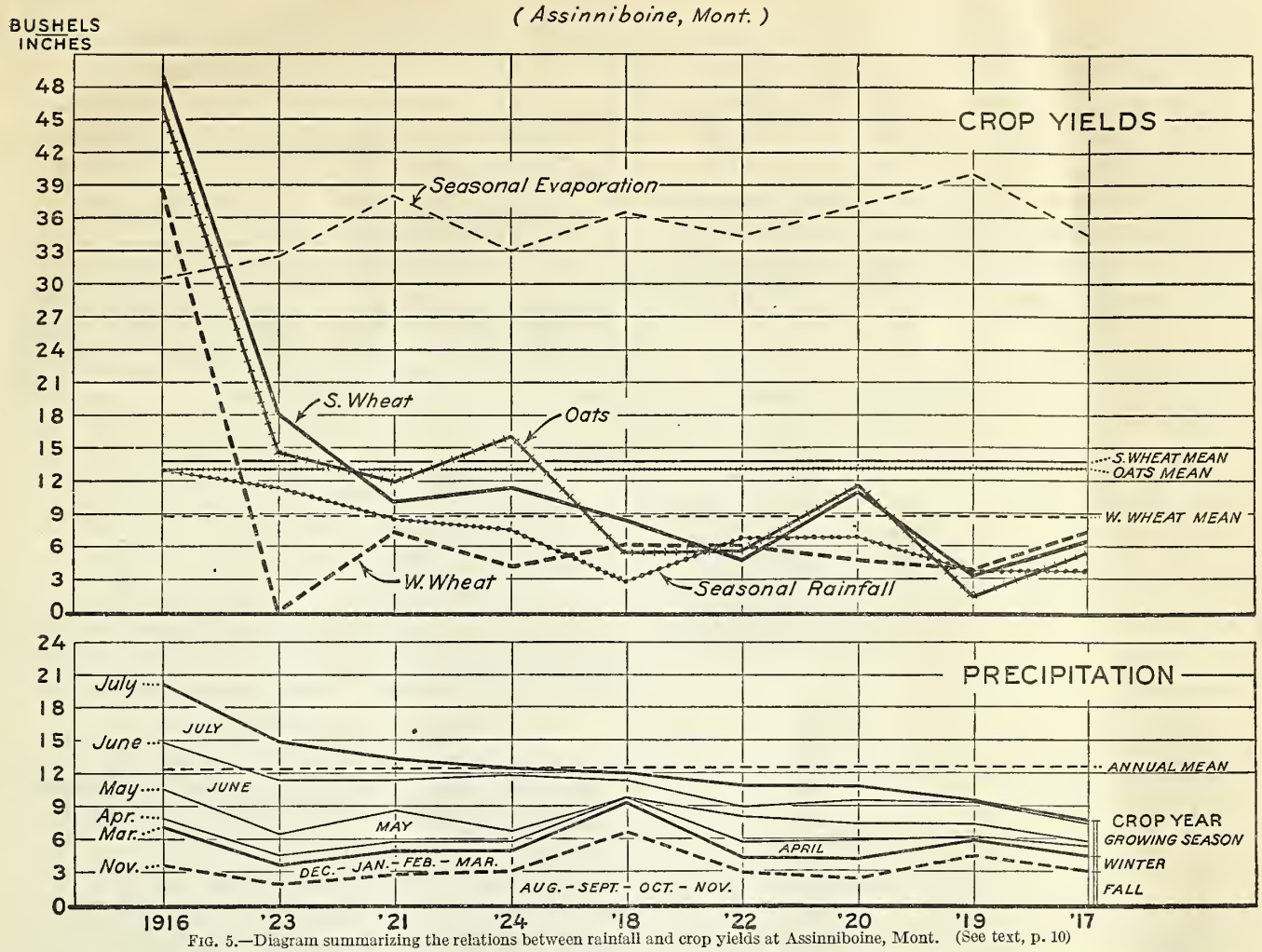


FIG. 5.—Diagram summarizing the relations between rainfall and crop yields at Assinniboine, Mont. (See text, p. 10)

RESULTS AT WILLISTON, N. DAK.

[Altitude, 1,875 feet; 12-year period (figs. 2 and 3)]

Climatic conditions: Mean annual precipitation, 14.68 inches; mean seasonal precipitation, 7.74 inches; mean seasonal evaporation, 33.103 inches.

Average frost-free period, 135 days.

Soil: Sandy loam, largely wind-blown loess.

Number of crop yields averaged each year: Barley, 5; spring wheat, 19; oats, 21; corn, 19.

Average annual crop yields per acre: Barley, 21 bushels; spring wheat, 16.1 bushels; oats, 35 bushels; corn, 4,282 pounds.

Crop year 1909

Precipitation:
- Annual, mean.
- Seasonal, 15 per cent above

Crop yields:
- Barley, 107 per cent above
- Spring wheat, 71 per cent above
- Oats, 87 per cent above
- Corn, 57 per cent above

Almost an ideal crop year. Although the annual precipitation was about normal, the seasonal precipitation was above the mean and well distributed. The barley crop was the best ever produced at the station; wheat, corn, and oats, the third largest. Frost-free period, 148 days.

Crop year 1910

Precipitation:
- Annual, 32 per cent below
- Seasonal, 27 per cent below

Crop yields:
- Barley, 93 per cent below
- Spring wheat, 89 per cent below
- Oats, 90 per cent below
- Corn, 58 per cent below

A dry year with a practical failure of all crops except corn, which made a good growth of stalks, but formed no ears except on fallow, and these did not mature. The corn was benefited by the August precipitation of the following crop year. The precipitation for all months except March and April of the crop year was below normal. Evaporation was 15 per cent above normal. Frost-free period, 114 days.

Crop year 1911

Precipitation:
- Annual, 32 per cent below
- Seasonal, 21 per cent below

Crop yields:
- Barley, 71 per cent below
- Spring wheat, 71 per cent below
- Oats, 69 per cent below
- Corn, 17 per cent below

Another dry year, the precipitation for both the crop year and the season being much below normal. The fact that crops did not fail as completely as in 1910 was attributed to the lack of hot days and hot winds which characterized that year. Corn and flax were considerably damaged by hail after small grains were in the shock. Corn was frosted August 21 and 22 before any ears matured. Frost-free period, 171 days.

Crop year 1912

Precipitation:
- Annual, 38 per cent above
- Seasonal, 53 per cent above

Crop yields:
- Barley, 103 per cent above
- Spring wheat, 130 per cent above
- Oats, 81 per cent above
- Corn (no data).

The only period of deficient precipitation was the last half of June, but crops were only beginning to show the effects of drought when rain came. Corn made a rank growth of stalks and formed large ears, but it was frosted September 16 before any of them matured. Frost-free period, 173 days.

Crop year 1913

Precipitation:
- Annual, 6 per cent below
- Seasonal, 22 per cent below

Crop yields:
- Barley, 9 per cent below
- Spring wheat, 6 per cent below
- Oats, 8 per cent above
- Corn (no data).

The fall of 1912 was abnormally wet, and the spring of 1913 opened with excellent prospects. Continued drought until June 27 depleted the soil water, and the small grain suffered. Drought again from the middle of July until harvest forced maturity. August rains provided optimum conditions for corn, which fully matured before the first killing frost, late in September. Frost-free period, 124 days.

Crop year 1914

Precipitation:
- Annual, 43 per cent above
- Seasonal, 55 per cent above

Crop yields:
- Barley, 75 per cent above
- Spring wheat, 60 per cent above
- Oats, 103 per cent above
- Corn, 78 per cent above

The water stored in the soil from rains which came after harvest in 1913 enabled the crops to make a good start and carry on until a heavy rainfall began on June 3. Prospective yields were somewhat reduced by a dry spell in July when small grains were filling. Corn did not lack for water at any time during the season and matured without material injury from frost. Frost-free period, 145 days.

Crop year 1915

Precipitation:
- Annual, 11 per cent below
- Seasonal, 7 per cent below

Crop yields:
- Barley, 33 per cent above
- Spring wheat, 49 per cent above
- Oats, 32 per cent above
- Corn, 44 per cent below

The precipitation was slightly below normal, but the temperature was low. Small grains suffered from a lack of rainfall in the latter part of July and in August until they were harvested, about the middle of the month. Late spring frosts, continued low temperatures until August, and drought in that month resulted in a very poor and immature corn crop. Frost-free period, 89 days.

Crop year 1916

Precipitation:
- Annual, 26 per cent above
- Seasonal, 19 per cent above

Crop yields:
- Barley, 93 per cent above
- Spring wheat, 72 per cent above
- Oats, 102 per cent above
- Corn, 70 per cent above

Corn was of good quality and fairly well matured. Frost-free period, 119 days.

Crop year 1917

Precipitation:
- Annual, 15 per cent below
- Seasonal, 46 per cent below

Crop yields:
- Barley, 46 per cent below
- Spring wheat, 36 per cent below
- Oats, 51 per cent below
- Corn, 32 per cent below

The precipitation of May, July, and August combined was only 0.66 inch. As a result of the drought the yields of all crops were much below their averages. Frost-free period, 146 days.

Crop year 1918

Precipitation:
- Annual, 22 per cent below
- Seasonal, 10 per cent below

Crop yields:
- Barley, 83 per cent below
- Spring wheat, 74 per cent below
- Oats, 82 per cent below
- Corn, 36 per cent above

There was no reserve water in the soil, and the ample precipitation of about the middle of April could not overcome the deficient precipitation of May and the still greater deficiency of June. The July and August precipitation made the corn crop. Frost-free period, 110 days.

Crop year 1919

Precipitation:
- Annual, 11 per cent above
- Seasonal, 6 per cent below

Crop yields:
- Barley, 80 per cent below
- Spring wheat, 75 per cent below
- Oats, 83 per cent below
- Corn, 35 per cent below

Climatic conditions were unusual. The spring was late and cold. Annual precipitation was 11 per cent above the mean; the seasonal precipitation only 6 per cent below. February, March, April, and May precipitations were above the mean, and June only slightly below, but there was no adequate rain after July 10. Frost-free period, 149 days.

Crop year 1920

Precipitation:
- Annual, 1 per cent below
- Seasonal, 5 per cent below

Crop yields:
- Barley, 31 per cent below
- Spring wheat, 32 per cent below
- Oats, 37 per cent below
- Corn, 55 per cent below

A rain of 2.3 inches on June 22 came with such force that it puddled the ground, beat down the crops, and largely ran off. Yields of small grains were about two-thirds of their averages. Corn formed but few ears. Frost-free period, 126 days.

RESULTS AT ASSINNIBOINE, MONT.

[Altitude, 2,305 feet; 9-year period (figs. 4 and 5)]

Climatic conditions: Mean annual precipitation, 12.36 inches; mean seasonal precipitation, 6.99 inches; mean seasonal evaporation, 35.214 inches.

Average frost-free period, 125 days.

Soil: Clay loam, glacial till.

Number of crop yields averaged each year: Winter wheat, 32; spring wheat, 30; oats, 58; corn, 48.

Average annual crop yields per acre: Winter wheat, 8.6 bushels; spring wheat 13.6 bushels; oats, 26 bushels; corn, 2,763 pounds.

Crop year 1916

Precipitation:
- Annual, 62 per cent above.
- Seasonal, 85 per cent above

Crop yields:
- Winter wheat, 349 per cent above.
- Spring wheat, 261 per cent above.
- Oats, 255 per cent above.
- Corn, 57 per cent above.

This was the first crop on land broken in June, 1915, and kept clean during the remainder of the season. There was some winterkilling of winter wheat, and the germination of oats was not uniform. About 90 per cent of the corn matured. All crops made vigorous growth and none of them suffered from drought at any time. Frost-free period, 120 days.

Crop year 1917

Precipitation:
- Annual, 38 per cent below
- Seasonal, 53 per cent below

Crop yields:
- Winter wheat, 16 per cent below
- Spring wheat, 53 per cent below
- Oats, 60 per cent below
- Corn, 62 per cent below

About a third of the winter wheat plats winterkilled and were reseeded to spring wheat, but this failed. On account of the drought none of the corn plats produced grain, although the season was long enough to have matured it. Frost-free period, 117 days.

Crop year 1918

Precipitation:
- Annual, 3 per cent below
- Seasonal, 60 per cent below

Crop yields:
- Winter wheat, 29 per cent below
- Spring wheat, 39 per cent below
- Oats, 60 per cent below
- Corn, 27 per cent below

A precipitation of 5.33 inches in September, 1917, raised the crop-year precipitation to nearly the mean. The several crops made yields ranging from 27 to 60 per cent below their averages. The production of crops of even this size was largely due to the fact that in the spring the soil was wet to a depth of 2 to 4 feet from the rains of the previous September. Frost-free period, 110 days.

Crop year 1919

Precipitation:
- Annual, 24 per eent below
- Seasonal, 49 per cent below

Crop yields:
- Winter wheat, 57 per cent below
- Spring wheat, 76 per cent below
- Oats, 90 per cent below
- Corn, 84 per cent below

One of the driest years in the history of the station and the year of lowest production of all crops except winter wheat, which failed entirely in 1923. Frost-free period, 136 days.

Crop year 1920

Precipitation:
- Annual, 13 per cent below
- Seasonal, 5 per cent below

Crop yields:
- Winter wheat, 46 per cent below
- Spring wheat, 21 per cent below
- Oats, 12 per cent below
- Corn, 16 per cent above

The distribution of the precipitation was very good, and there were no extended periods of severe drought. There was little water in the soil when spring opened, and the yields were somewhat below normal. Winter wheat winterkilled and was reseeded to Marquis. The reseeding was late, and the yield was 46 per cent below the average yield of winter wheat. Ears set on about half the corn plants but did not mature. Frost-free period, 143 days.

Crop year 1921

Precipitation:
- Annual, 8 per cent above
- Seasonal, 21 per cent above

Crop yields:
- Winter wheat, 16 per cent below
- Spring wheat, 26 per cent below
- Oats, 9 per cent below
- Corn, 3 per cent above

The yields of winter wheat and corn were reduced by loss of stand resulting from an attack of the pale western cutworm in the spring. Frost-free period, 103 days.

Crop year 1922

Precipitation:
- Annual, 13 per cent below
- Seasonal, 6 per cent below

Crop yield:
- Winter wheat, 30 per eent below
- Spring wheat, 65 per cent below
- Oats, 58 per cent below
- Corn, 2 per cent below

The precipitation in June was less than a third of the normal, and the drought at that time was very injurious. The total yield of corn was about normal, but because of the dry August there were but few ears. Winter wheat was winterkilled and killed by pale western cutworms. It was all reseeded to Marquis and because of the later seeding was damaged less by the June drought than spring wheat and oats sown at the usual time. Frost-free period, 145 days.

Crop year 1923

Precipitation:
- Annual, 20 per cent above
- Seasonal, 61 per cent above

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 34 per cent above
- Oats, 11 per cent above
- Corn, 62 per cent above

The fall of 1922 was so dry that winter wheat was not seeded until too late to make any fall growth. With unfavorable spring conditions it was not able to overcome the competition of Russian thistles, although some plats were reseeded to spring wheat. Spring wheat suffered somewhat from drought and hot winds in the early season, but was favored by the heavy rainfall of June and July and made a crop exceeded only by that of 1916. The season was very favorable for corn, which matured about 25 bushels of grain per acre. The total yield of corn was the highest recorded in the nine years' history of the station. Frost-free period, 135 days.

Crop year 1924

Precipitation:
- Annual, mean.
- Seasonal, 7 per cent above

Crop yields:
- Winter wheat, 52 per cent below
- Spring wheat, 18 per cent below
- Oats, 23 per cent above
- Corn, 33 per cent above

The fall was so dry that none of the winter wheat emerged until spring, and most of the plats were reseeded to spring wheat. The reseeded plats were late and failed entirely. The only winter wheat produced was on fallow and disked corn ground. Drought became effective about the middle of July, and spring wheat which did not mature until the middle of August was injured much more than oats, which matured the last of July. Corn was injured by hail on August 1, but the crop matured more than an average yield. Frost-free period, 119 days.

RESULTS AT MOCCASIN, MONT.

[Altitude, 3,960 feet; 17-year period (figs. 6 and 7)]

Climatic conditions: Mean annual precipitation, 17.11 inches; mean seasonal precipitation, 8.88 inches; mean seasonal evaporation, 33.348 inches.

Average frost-free period, 124 days.

Soil: Rich black prairie loam overlying gravel more or less cemented by lime deposits.

Number of crop yields averaged each year: Winter wheat, 6; spring wheat, 25; oats, 31; corn, 29.

Average annual crop yields per acre: Winter wheat, 17.1 bushels; spring wheat, 17.6 bushels; oats, 36.1 bushels; corn fodder, 4,578 pounds.

Crop year 1908

Precipitation:
- Annual, 12 per cent below
- Seasonal, 19 per cent above

Crop yields:
- Winter wheat (no crop sown).
- Spring wheat, 75 per cent below
- Oats, 52 per cent below
- Corn, 49 per cent below

The land was broken in July, 1907, and the crop of 1908 was the first at this station. Winter wheat was not sown. Spring grains were sown late and suffered from the drought which began early in June and continued through the growing season. Frost-free period, no data.

Crop year 1909

Precipitation:
- Annual, 30 per cent above
- Seasonal, 23 per cent above

Crop yields:
- Winter wheat, 179 per cent above
- Spring wheat, 94 per cent above
- Oats, 85 per cent above
- Corn, 107 per cent above

The yields of all crops were among the highest recorded at this station. Frost-free period, 148 days.

MOCCASIN (MONT.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1907	4	1.47	.73	.20	T	T	.55	.49	98	61	7.31	245	.20	14.99	W.WHEAT		1908
	3														S.WHEAT	4.4	
	2														OATS	17.3	
	1														CORN #	2305.0	
1908	4	1.18	1.41	6.27	T	.22	.90	08	1 22	1 03	1 34	5.99	2.54	22.18	W.WHEAT	47.8	1909
	3														S.WHEAT	34.1	
	2														OATS	66.6	
	1														CORN #	9456.0	
1909	4	4.21	4.47	.49	.30	1.21	.09	.74	10	1.31	2.40	1.69	1.10	18.11	W.WHEAT	22.9	1910
	3														S.WHEAT	10.6	
	2														OATS	22.2	
	1														CORN #	2641.0	
1910	4	2.02	2.54	1.36	1.26	.48	58	.55	.54	1.66	2.98	2.55	.50	17.02	W.WHEAT	25.4	1911
	3														S.WHEAT	22.6	
	2														OATS	51.5	
	1														CORN #	5981.0	
1911	4	6.34	1.37	1 94	1 76	68	88	60	81	1.43	3.94	.64	1 92	22.31	W.WHEAT	12.9	1912
	3														S.WHEAT	0.0	
	2														OATS	0.0	
	1														CORN #	2329.0	
1912	4	1.27	1.63	1.68	.14	06	89	09	20	.79	2 64	4 77	1.12	15.28	W.WHEAT	27.1	1913
	3														S.WHEAT	23.8	
	2														OATS	64.4	
	1														CORN #	4215.0	
1913	4	.51	1.01	1.83	.93	.38	.47	1.35	1.12	1.19	2.91	4.64	.64	16.78	W.WHEAT	19.4	1914
	3														S.WHEAT	18.4	
	2														OATS	49.5	
	1														CORN #	4310.0	
1914	4	.65	1.11	.74	.64	.21	.76	.08	2.69	1.43	2.12	3.97	3.54	17.94	W.WHEAT	35.2	1915
	3														S.WHEAT	32.4	
	2														OATS	70.7	
	1														CORN #	6144.0	
1915	4	.92	2.65	.85	1.01	66	.74	1.22	1.33	1.20	2.25	3.97	2.03	18.83	W.WHEAT	0.0	1916
	3														S.WHEAT	23.2	
	2														OATS	47.9	
	1														CORN #	4423.0	
1916	4	1.28	1.81	1.00	.64	2.39	1.87	1.30	.85	1.18	2.79	1.81	.96	17.88	W.WHEAT	0.0	1917
	3														S.WHEAT	9.9	
	2														OATS	16.3	
	1														CORN #	3368.0	
1917	4	.75	2.91	.62	.09	2.56	2.34	.62	.57	.44	2.69	1.55	2.95	18.09	W.WHEAT	17.6	1918
	3														S.WHEAT	20.1	
	2														OATS	39.6	
	1														CORN #	7152.0	
1918	4	1.48	1.25	1.09	1.14	.26	.13	.71	1.20	.17	73	1.08	1.02	10.26	W.WHEAT	1.9	1919
	3														S.WHEAT	3.2	
	2														OATS	4.1	
	1														CORN #	937.0	
1919	4	.29	1.48	1.43	.93	.73	.70	.63	.39	5.37	2.91	3.97	.89	19.72	W.WHEAT	5.8	1920
	3														S.WHEAT	15.2	
	2														OATS	31.7	
	1														CORN #	5565.0	
1920	4	1.83	.66	.85	.15	.21	.08	T	.60	.50	3.31	2.45	3.87	14.29	W.WHEAT	0.0	1921
	3														S.WHEAT	19.6	
	2														OATS	23.7	
	1														CORN #	4294.0	
1921	4	1.03	1.89	.03	1.47	.47	.67	69	.29	2.12	1.42	4.43	1.10	15.41	W.WHEAT	25.6	1922
	3														S.WHEAT	20.7	
	2														OATS	46.3	
	1														CORN #	4161.0	
1922	4	.68	.51	.77	1.19	1.51	.17	1.08	.69	.48	2.75	5.30	3.20	18.33	W.WHEAT	10.4	1923
	3														S.WHEAT	22.8	
	2														OATS	46.5	
	1														CORN #	6601.0	
1923	4	2.68	1.03	.48	.15	.57	.54	.27	.86	.87	1.25	3.37	1.39	13.46	W.WHEAT	21.0	1924
	3														S.WHEAT	17.6	
	2														OATS	16.0	
	1														CORN #	3945.0	
AVERAGE		1.68	1.66	1.25	.70	.74	.73	.62	.85	1.28	2.69	3.21	1.70	17.11			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	# Corn fodder in pounds		

FIG. 6.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Moccasin (Mont.) Field Station

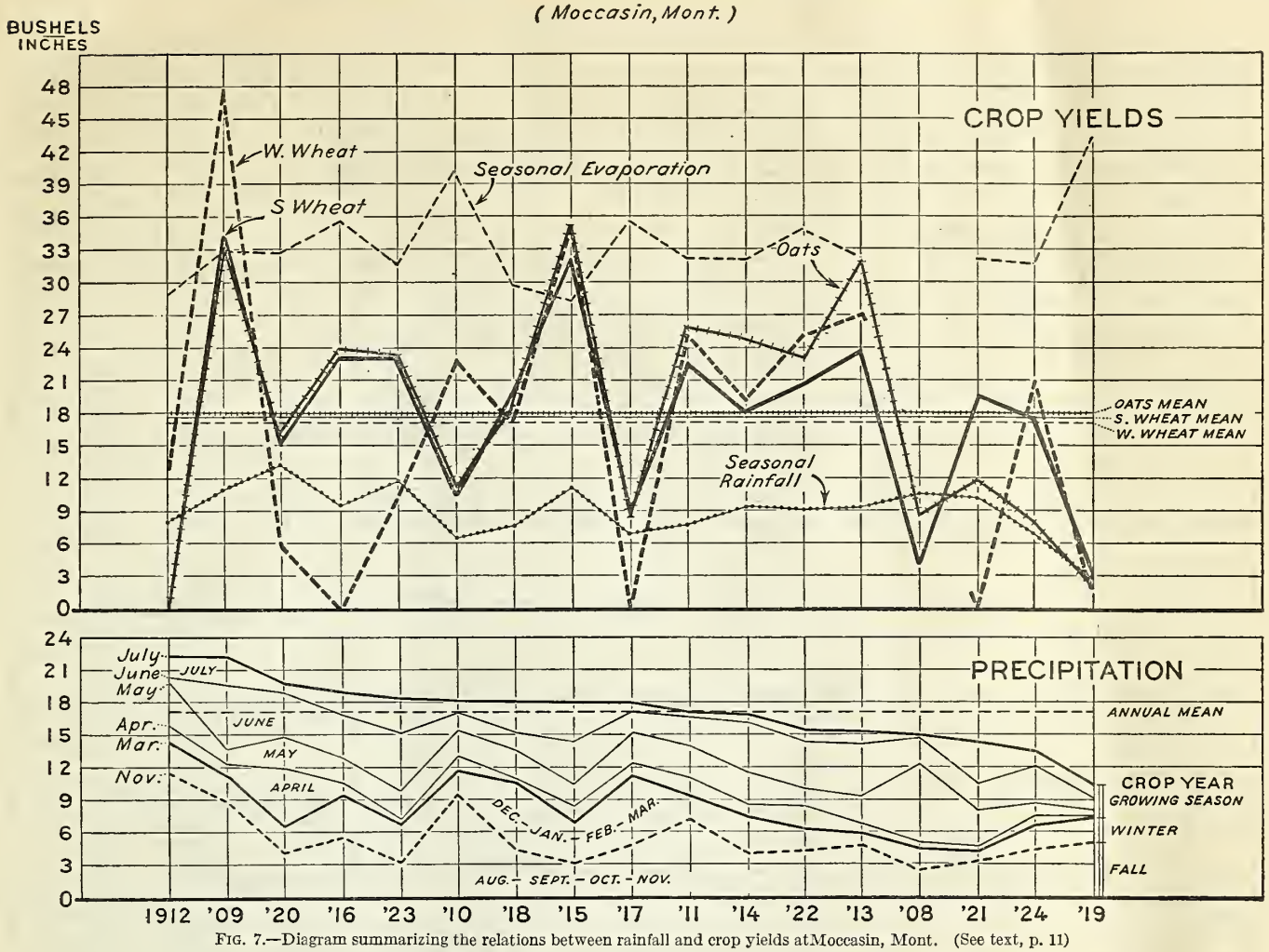


FIG. 7.—Diagram summarizing the relations between rainfall and crop yields at Moccasin, Mont. (See text, p. 11)

Crop year 1910

Precipitation:
- Annual, 6 per cent above
- Seasonal, 27 per cent below

Crop yields:
- Winter wheat, 34 per cent above
- Spring wheat, 40 per cent below
- Oats, 38 per cent below
- Corn, 42 per cent below

The precipitation was deficient during the most of July and the first part of August. Winter wheat yielded a good crop, but spring-sown grains and corn, being later, were affected more by the drought. Frost-free period, 83 days.

Crop year 1911

Precipitation:
- Annual, 1 per cent below
- Seasonal, 13 per cent below

Crop yields:
- Winter wheat, 49 per cent above
- Spring wheat, 29 per cent above
- Oats, 43 per cent above
- Corn, 31 per cent above

In spite of a dry July, winter wheat and oats which matured before the end of the month made good yields. The drought was broken on August 1, and spring wheat which did not mature for another month made a good crop. The yield of corn also was good. Frost-free period, 135 days.

Crop year 1912

Precipitation:
- Annual, 30 per cent above
- Seasonal, 11 per cent below

Crop yields:
- Winter wheat, 24 per cent below
- Spring wheat, 100 per cent below
- Oats, 100 per cent below
- Corn, 49 per cent below

The heavy precipitation of August, 1911, made the crop-year precipitation for the year ending July 31, 1912, the highest in the the record, but the seasonal precipitation was 11 per cent below the mean. Crops were badly damaged in the last 15 days of June by drought. Hail on July 11 destroyed the spring-sown small grains. Winter wheat was further developed. It was severely injured but matured a crop 24 per cent below the mean. Corn recovered sufficiently to produce half its average yield of fodder. Frost-free period, 126 days.

Crop year 1913

Precipitation:
- Annual, 11 per cent below
- Seasonal, 5 per cent above

Crop yields:
- Winter wheat, 59 per cent above
- Spring wheat, 35 per cent above
- Oats, 78 per cent above
- Corn, 8 per cent below

The yields of small grains were from 35 to 78 per cent above their means. The lower yield was from spring wheat, which did not mature until August 24 and was affected the most by the dry weather after the middle of July. Frost-free period, 113 days.

Crop year 1914

Precipitation:
- Annual, 2 per cent below
- Seasonal, 6 per cent above

Crop yields:
- Winter wheat, 13 per cent above
- Spring wheat, 5 per cent above
- Oats, 37 per cent above
- Corn, 6 per cent below

Conditions were ideal for plant growth until about July 10. From that time until harvest, conditions were most adverse. Small-grain harvest ranged from August 2 for oats to August 15 for wheat. In spite of the fact that the drought preceding

HUNTLEY (MONT.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1911	4	1.05	.57	.88	.82	.13	.27	.21	.41	2.00	2.44	1.64	2.75	13.17	W.WHEAT		1912
	3														S.WHEAT	7.3	
	2														OATS	8.7	
	1														CORN	16.7	
1912	4	1.39	2.97	3.25	.75	.00	.29	.10	.40	.43	1.27	2.20	1.10	14.15	W.WHEAT	36.0	1913
	3														S.WHEAT	18.2	
	2														OATS	45.6	
	1														CORN	27.3	
1913	4	1.19	1.43	2.89	.45	.17	.11	.19	.52	1.16	2.83	3.31	.05	14.30	W.WHEAT	33.2	1914
	3														S.WHEAT	24.8	
	2														OATS	56.7	
	1														CORN	21.5	
1914	4	.76	1.90	1.07	.07	.24	.41	.02	.78	.23	2.50	5.99	3.11	17.08	W.WHEAT	38.1	1915
	3														S.WHEAT	35.6	
	2														OATS	78.9	
	1														CORN	39.0	
1915	4	.50	1.64	.31	1.34	.71	.46	.24	1.02	.89	1.81	2.11	1.50	12.53	W.WHEAT	18.0	1916
	3														S.WHEAT	14.2	
	2														OATS	28.6	
	1														CORN	20.4	
1916	4	.39	1.16	1.34	1.07	1.50	.76	.49	1.41	1.01	2.88	2.75	.37	15.13	W.WHEAT	16.5	1917
	3														S.WHEAT	12.1	
	2														OATS	23.4	
	1														CORN	27.5	
1917	4	.24	.83	.75	.07	3.58	2.42	.33	.59	.67	2.09	1.20	1.29	14.06	W.WHEAT	13.7	1918
	3														S.WHEAT	14.2	
	2														OATS	24.1	
	1														CORN	22.9	
1918	4	1.18	1.87	.53	1.20	.09	.22	.35	.67	.54	.83	.21	.63	8.32	W.WHEAT	5.6	1919
	3														S.WHEAT	0.8	
	2														OATS	0.8	
	1														CORN	0.0	
1919	4	.63	2.47	2.61	1.96	1.10	.75	1.28	1.17	2.03	2.47	2.46	1.58	20.51	W.WHEAT	28.7	1920
	3														S.WHEAT	12.4	
	2														OATS	30.2	
	1														CORN	20.2	
1920	4	1.01	.32	.20	.05	.48	.25	.30	1.38	.72	3.85	2.19	.83	11.58	W.WHEAT	11.4	1921
	3														S.WHEAT	9.8	
	2														OATS	19.4	
	1														CORN	1.0	
1921	4	.19	.66	.21	1.72	.30	1.75	.80	.30	3.55	2.65	4.68	1.75	18.56	W.WHEAT	27.3	1922
	3														S.WHEAT	24.3	
	2														OATS	55.7	
	1														CORN	26.4	
1922	4	.84	.34	.49	1.27	1.53	.18	.18	.43	1.48	1.66	2.60	3.17	14.17	W.WHEAT	18.6	1923
	3														S.WHEAT	11.4	
	2														OATS	26.0	
	1														CORN	9.0	
1923	4	2.16	4.29	1.15	.10	.66	.53	.56	2.26	.87	1.55	2.48	1.59	18.20	W.WHEAT	28.4	1924
	3														S.WHEAT	28.3	
	2														OATS	55.0	
	1														CORN	36.0	
AVERAGE		.89	1.57	1.21	.84	.81	.65	.38	.87	1.20	2.22	2.60	1.52	14.76			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 8.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Huntley (Mont.) Field Station

harvest ripened the crops prematurely and prevented them from filling well, the yields were above the averages. Frost-free period, 123 days.

Crop year 1915

Precipitation:
- Annual, 5 per cent above
- Seasonal, 25 per cent above

Crop yields:
- Winter wheat, 106 per cent above
- Spring wheat, 84 per cent above
- Oats, 96 per cent above
- Corn, 34 per cent above

The distribution of the rainfall was all that could be asked. Good yields were obtained with all crops under all methods. The only year that equaled or exceeded it in production was 1909. Frost-free period, 129 days.

Crop year 1916

Precipitation:
- Annual, 10 per cent above
- Seasonal, 7 per cent above

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 32 per cent above
- Oats, 33 per cent above
- Corn, 3 per cent below

All winter wheat winterkilled. From July 15 until harvest, spring grains suffered more or less from lack of water but made good yields. Frost-free period, 120 days.

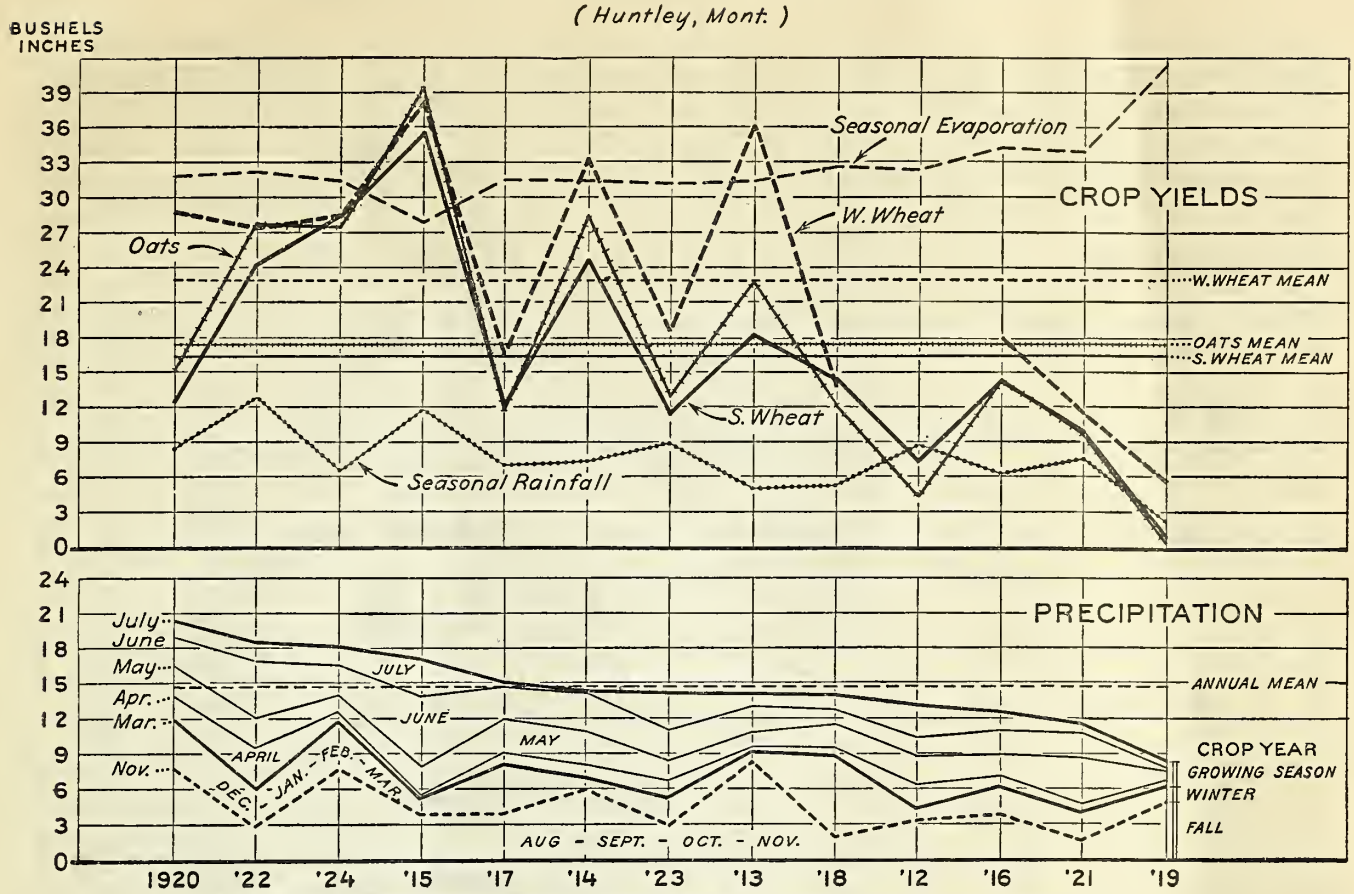


FIG. 9.—Diagram summarizing the relations between rainfall and crop yields at Huntley, Mont. (See text, p. 18)

Crop year 1917

Precipitation:
- Annual, 5 per cent above
- Seasonal, 24 per cent below

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 44 per cent below
- Oats, 55 per cent below
- Corn, 26 per cent below

All winter wheat winterkilled Droughty conditions prevailed from the middle of June until after harvest, so crop yields were low all over the Judith Basin. Frost-free period, 140 days.

Crop year 1918

Precipitation:
- Annual, 6 per cent above
- Seasonal, 13 per cent below

Crop yields:
- Winter wheat, 3 per cent above
- Spring wheat, 14 per cent above
- Oats, 10 per cent above
- Corn, 56 per cent above

Cool, dry weather generally prevailed during the spring months, and crop growth was very slow. June was hot and dry, and crop prospects were very poor until July 13, when good rains ensued. Late-maturing crops or varieties were especially benefited by the late rains. Winter wheat came through the winter with fair stands and made about the average yield. Frost-free period, 109 days.

Crop year 1919

Precipitation:
- Annual, 40 per cent below
- Seasonal, 66 per cent below

Crop yields:
- Winter wheat, 89 per cent below
- Spring wheat, 82 per cent below
- Oats, 82 per cent below
- Corn, 80 per cent below

The winter of 1918–19 was unusually mild, and winter wheat came through with the best stand since 1915. The drought which started in April continued through the summer, and yields of grains were the lowest ever obtained in the Judith Basin. Frost-free period, 118 days.

Crop year 1920

Precipitation:
- Annual, 15 per cent above
- Seasonal, 48 per cent above

Crop yields:
- Winter wheat, 66 per cent below
- Spring wheat, 14 per cent below
- Oats, 12 per cent below
- Corn, 22 per cent above

The spring of 1920 was the most backward in the history of the station and was characterized by unusually low temperatures and an abundance of precipitation. The wet spring and early summer were followed by a drought in July and August which seriously affected all crops, the crop season as a whole being from three to four weeks later than usual. Corn was benefited by rain late in August and was the only crop to produce a yield above the average. Frost-free period, 126 days.

Crop year 1921

Precipitation:
- Annual, 16 per cent below
- Seasonal, 14 per cent above

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 11 per cent above
- Oats, 34 per cent below
- Corn, 8 per cent below

Winter wheat was winterkilled by a dry and open winter. The quantity and distribution of precipitation from May 6 to July 10 was very favorable to crop production. On the latter date crops were damaged by hail, the greatest injury being to oats. Exceptionally hot, dry weather followed in July and August. Frost-free period, 130 days.

DICKINSON (N. DAK.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1906	4	2.64	.25	.14	.87	.76	.80	.14	.39	.30	1.38	2.68	4.82	15.17	BARLEY	40.2	1907
	3														S.WHEAT	31.8	
	2														OATS	46.8	
	1														CORN	0.0	
1907	4	1.93	1.22	.04	.02	.22	.28	.73	1.42	1.27	3.79	4.06	1.34	16.32	BARLEY	33.5	1908
	3														S.WHEAT	30.0	
	2														OATS	53.4	
	1														CORN	0.0	
1908	4	1.36	1.55	2.47	.78	.24	.27	.52	.25	.60	6.04	3.02	1.87	18.97	BARLEY	46.4	1909
	3														S.WHEAT	36.0	
	2														OATS	67.8	
	1														CORN	50.0	
1909	4	5.54	.72	1.08	.29	1.02	.34	.97	.82	1.71	1.26	3.03	2.35	19.13	BARLEY	26.4	1910
	3														S.WHEAT	21.7	
	2														OATS	35.4	
	1														CORN	22.0	
1910	4	1.48	.49	.54	.15	.15	.90	.55	.43	.48	1.63	2.61	1.29	10.70	BARLEY	9.0	1911
	3														S.WHEAT	5.9	
	2														OATS	8.9	
	1														CORN	0.0	
1911	4	1.69	2.53	2.09	.56	.22	.41	.12	.50	2.51	3.99	2.06	3.90	20.58	BARLEY	0.0	* 1912
	3														S.WHEAT	0.0	
	2														OATS	0.0	
	1														CORN	0.0	
1912	4	2.71	1.81	1.15	.18	T	.13	.04	1.22	.59	1.69	1.83	1.26	12.55	BARLEY	31.2	1913
	3														S.WHEAT	25.9	
	2														OATS	55.5	
	1														CORN	27.6	
1913	4	2.79	.97	1.04	.43	T	.04	.43	1.27	.80	2.60	7.60	5.54	23.51	BARLEY	26.6	1914
	3														S.WHEAT	15.4	
	2														OATS	24.6	
	1														CORN	19.0	
1914	4	2.20	1.21	.42	.25	.29	.07	.15	.21	.73	3.98	5.89	3.81	19.21	BARLEY	57.0	1915
	3														S.WHEAT	37.0	
	2														OATS	93.4	
	1														CORN	0.0	
1915	4	.36	2.17	1.79	1.15	.22	.80	.32	.47	2.57	2.52	3.80	2.37	18.54	BARLEY	30.1	1916
	3														S.WHEAT	23.3	
	2														OATS	67.2	
	1														CORN	17.8	
1916	4	1.93	.70	1.10	.38	.98	.60	.23	.48	1.18	.36	2.54	1.40	11.88	BARLEY	7.7	1917
	3														S.WHEAT	12.6	
	2														OATS	17.9	
	1														CORN	0.0	
1917	4	1.43	.20	.22	T	.61	.39	.25	.31	2.11	1.67	1.61	1.73	10.53	BARLEY	3.8	1918
	3														S.WHEAT	9.3	
	2														OATS	7.9	
	1														CORN	0.0	
1918	4	2.99	.48	.42	.10	.30	T	.67	.79	1.14	2.41	.52	.53	10.35	BARLEY	1.2	1919
	3														S.WHEAT	3.8	
	2														OATS	3.0	
	1														CORN	9.7	
1919	4	.51	.71	.57	.34	.16	.79	.05	.18	.79	1.64	4.16	2.81	12.71	BARLEY	25.6	1920
	3														S.WHEAT	19.2	
	2														OATS	38.7	
	1														CORN	14.3	
1920	4	2.33	1.74	1.11	.10	.18	.22	.28	1.01	1.02	1.78	3.09	1.61	14.47	BARLEY	4.4	1921
	3														S.WHEAT	5.8	
	2														OATS	11.0	
	1														CORN	9.0	
1921	4	2.73	2.15	.13	1.05	.61	.32	.99	.29	1.11	1.97	6.57	1.92	19.84	BARLEY	43.6	1922
	3														S.WHEAT	30.0	
	2														OATS	73.0	
	1														CORN	25.3	
1922	4	.74	1.23	.58	1.72	.58	.30	.20	.37	1.77	1.24	4.55	4.67	17.95	BARLEY	27.9	1923
	3														S.WHEAT	18.1	
	2														OATS	45.9	
	1														CORN	48.5	
1923	4	.82	4.55	.77	.31	.18	.03	.34	1.11	1.03	1.12	3.26	3.03	16.55	BARLEY	24.6	1924
	3														S.WHEAT	21.7	
	2														OATS	60.5	
	1														CORN	28.4	
AVERAGE		2.01	1.37	.87	.48	.37	.37	.39	.64	1.21	2.28	3.49	2.57	16.05			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	* Crop hailed out in 1912 but included in average		

FIG. 10.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Dickinson (N. Dak.) Field Station

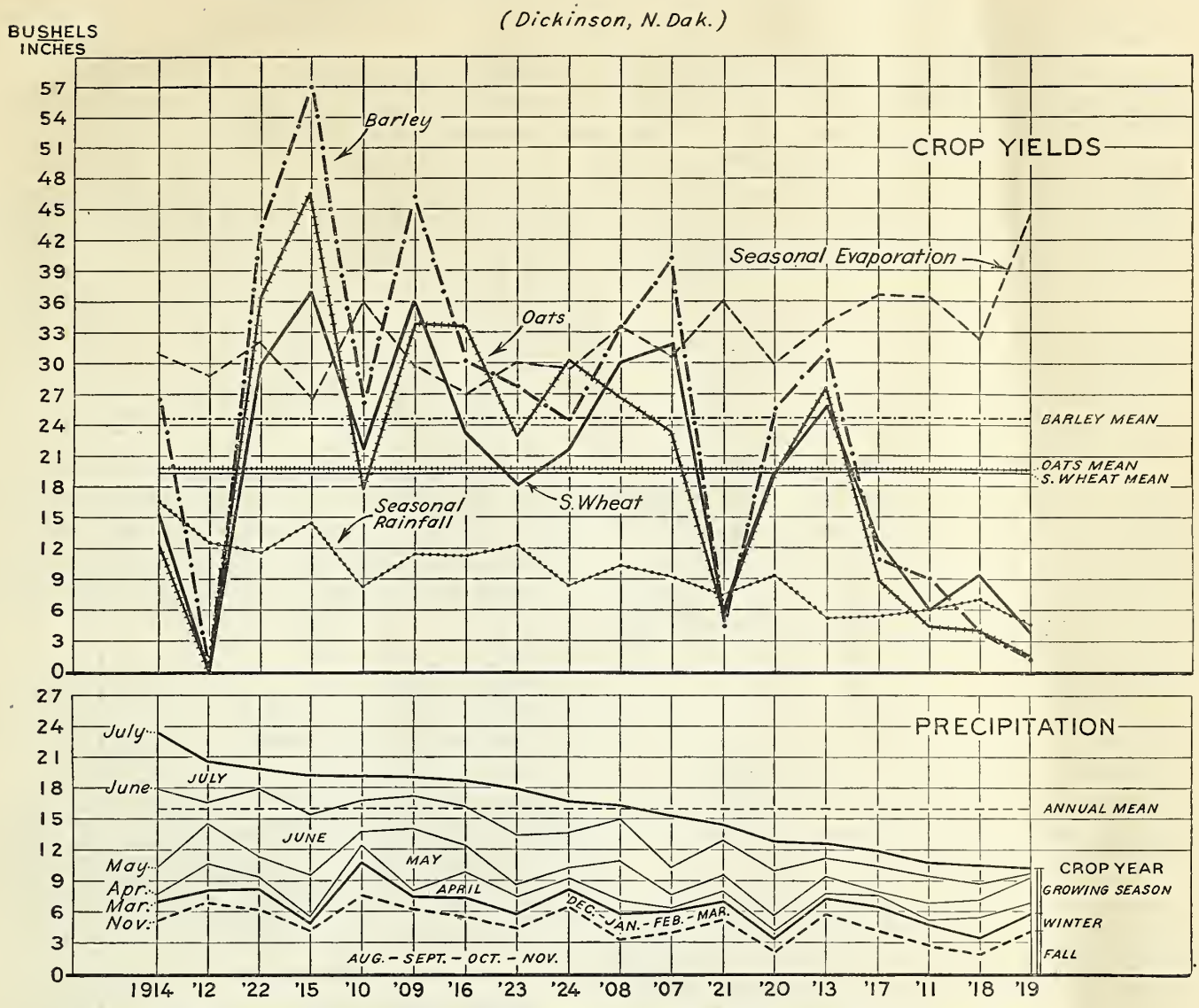


FIG. 11.—Diagram summarizing the relations between rainfall and crop yields at Dickinson, N. Dak. (See text, p. 19)

Crop year 1922

Precipitation:
- Annual, 10 per cent below
- Seasonal, 2 per cent above

Crop yields:
- Winter wheat, 50 per cent above
- Spring wheat, 18 per cent above
- Oats, 28 per cent above
- Corn, 9 per cent below

The winter of 1921–22 was extremely long and cold, but there was an abundance of moisture, and the ground was covered with snow during the greater portion of the time. Winter wheat survived the winter with little loss. Spring was rather late, but an abundance of rain was received, especially during June, and conditions were very favorable to crop growth until the middle of July. Hot, dry weather prevailed during July and August and did considerable damage to late-maturing spring grain. Spring wheat suffered more than oats because it was later. Corn suffered from the continued late drought more seriously than the small grains and was also damaged to some extent by grasshoppers. Frost-free period, 150 days.

Crop year 1923

Precipitation:
- Annual, 7 per cent above
- Seasonal, 32 per cent above

Crop yields:
- Winter wheat, 29 per cent below
- Spring wheat, 30 per cent above
- Oats, 29 per cent above
- Corn, 44 per cent above

Winter wheat was partially winterkilled. An abundance of precipitation from the middle of May to the end of August with other climatic factors favorable made conditions almost ideal for crop growth. Crops apparently did not lack for water at any time during the season, but all crops were damaged by hail on July 8. Corn produced the largest ears that have developed at the station and reached an unusual degree of maturity. Frost-free period, 119 days.

Crop year 1924

Precipitation:
- Annual, 21 per cent below
- Seasonal, 22 per cent below

Crop yields:
- Winter wheat, 23 per cent above
- Spring wheat, mean.
- Oats, 56 per cent below
- Corn, 14 per cent below

The season and crop year of 1924 were next to the driest in the history of the station, both the seasonal and crop-year precipitation being about 20 per cent below their respective means. A very favorable distribution of the rainfall with evaporation and temperature lower than normal made the year much more favorable to crop production as a whole than the quantity of precipitation would indicate, but the lack of water during the greater part of August and September made conditions very unfavorable for late crops. A heavy hailstorm on August 5 did considerable damage to oats and corn, but other crops were injured to only a slight extent. Frost-free period, 107 days.

RESULTS AT HUNTLEY, MONT.

[Altitude, 3,018 feet; 13-year period (figs. 8 and 9)]

Climatic conditions: Mean annual precipitation, 14.76 inches; mean seasonal precipitation, 7.54 inches; mean seasonal evaporation, 32.497 inches.

Average frost-free period, 134 days.

Soil: Clay loam of sedimentary deposit, second bench lying above irrigation ditch level.

Number of crop yields averaged each year: Winter wheat, 25; spring wheat, 36; oats, 34; corn, 41.

Average annual crop yields per acre: Winter wheat, 23 bushels; spring wheat, 16.4 bushels; oats, 34.9 bushels; corn, 20.6 bushels.

Crop year 1912

Precipitation:
- Annual, 11 per cent below
- Seasonal, 17 per cent above

Crop yields:
- Winter wheat (no crop sown).
- Spring wheat, 55 per cent below
- Oats, 75 per cent below
- Corn, 19 per cent below

The ground was broken in August, 1911. Winter wheat was not sown. There was little water in the soil at seeding time in April, but a good rainfall in the latter part of the month and in May brought on a good stand of most crops and gave them good growth. A drought during June severely injured small grains, especially oats and barley, which did not fill properly and were almost failures. A heavy rain on July 2 came in time to benefit wheat, which filled fairly well. During the latter part of July and the month of August drought injured corn, which was soft and not well filled when harvested. Frost-free period, 126 days.

Crop year 1913

Precipitation:
- Annual, 6 per cent below
- Seasonal, 34 per cent below

Crop yields:
- Winter wheat, 57 per cent above
- Spring wheat, 11 per cent above
- Oats, 31 per cent above
- Corn, 33 per cent above

The water stored in the soil from the precipitation of the preceding fall and the very good distribution of the seasonal precipitation to a large extent overcame the possible ill effects of the deficiency in the quantity of rainfall. Crops suffered but little from drought. The yield of winter wheat was exceptionally high, because it all followed either fallow or green manure. This condition was peculiar to this year alone and was incident to starting rotations. Frost-free period, 142 days.

Crop year 1914

Precipitation:
- Annual, 3 per cent below
- Seasonal, 3 per cent below

Crop yields:
- Winter wheat, 44 per cent above
- Spring wheat, 51 per cent above
- Oats, 62 per cent above
- Corn, 4 per cent above

The distribution of the precipitation was very favorable to small grains, which grew and matured normally. Corn suffered from drought in the latter part of its season. Frost-free period, 154 days.

Crop year 1915

Precipitation:
- Annual, 16 per cent above
- Seasonal, 57 per cent above

Crop yields:
- Winter wheat, 66 per cent above
- Spring wheat, 117 per cent above
- Oats, 126 per cent above
- Corn, 89 per cent above

All yields of small grains, especially the spring grains and flax, were good. June was so cool that the early growth of corn was badly retarded, but there was no drought. The first killing frost was rather late, and the yield of corn was high. Frost-free period, 154 days.

Crop year 1916

Precipitation:
- Annual, 15 per cent below
- Seasonal, 16 per cent below

Crop yields:
- Winter wheat, 22 per cent below
- Spring wheat, 13 per cent below
- Oats, 17 per cent below
- Corn, 1 per cent below

Throughout the season all crops were free from diseases and insect pests, but all suffered to a greater or less extent from drought, and as a result yields were generally low and the quality poor. Frost-free period, 126 days.

Crop year 1917

Precipitation:
- Annual, 3 per cent above
- Seasonal, 7 per cent below

Crop yields:
- Winter wheat, 28 per cent below
- Spring wheat, 26 per cent below
- Oats, 33 per cent below
- Corn, 33 per cent above

The spring was late. Crops made satisfactory growth while the water of the May and June rainfall lasted, but very hot and dry weather later when the grains were filling made for generally low yields and poor quality of small grains. In spite of the very deficient precipitation in July and August, corn showed practically no signs of drought and gave a yield above the average in both quantity and quality. Frost-free period, 130 days.

Crop year 1918

Precipitation:
- Annual, 5 per cent below
- Seasonal, 30 per cent below

Crop yields:
- Winter wheat, 40 per cent below
- Spring wheat, 13 per cent below
- Oats, 31 per cent below
- Corn, 11 per cent above

Exceptionally heavy snowfall in December and January brought the crop-year precipitation up to within 5 per cent of the mean. Because of drought and hot weather in June, small grains made yields generally lower and of poorer quality than the average. The condition that injured the small grains favored corn. The yield of both grain and stover was above the average, although the yield of grain would have been increased by more rainfall in July and August. Frost-free period, 138 days.

Crop year 1919

Precipitation:
- Annual, 44 per cent below
- Seasonal, 71 per cent below

Crop yields:
- Winter wheat, 76 per cent below
- Spring wheat, 95 per cent below
- Oats, 98 per cent below
- Corn, 100 per cent below

Because of the severe drought all crops gave yields so low that they were practically failures. With the exception of crops grown after fallow or green manure, nearly all yields were less than a bushel to the acre, and in many cases there were no returns whatever. Many plats did not head. The corn on all plats dried up without forming grain. Frost-free period, 140 days.

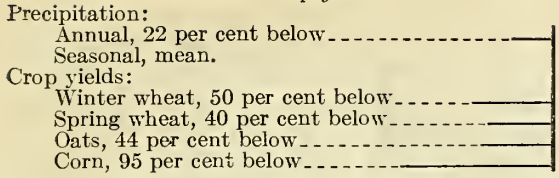
Crop year 1920

Precipitation:
- Annual, 39 per cent above
- Seasonal, 13 per cent above

Crop yields:
- Winter wheat, 25 per cent above
- Spring wheat, 24 per cent below
- Oats, 13 per cent below
- Corn, 2 per cent below

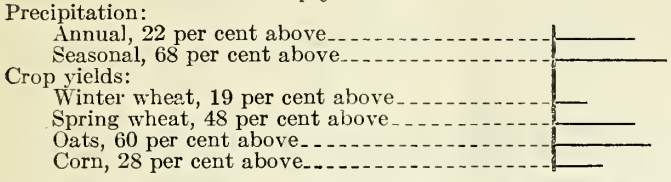
The spring was so cold and wet that seeding did not begin until May 20, much later than usual. The rainfall of May and June stimulated a heavy growth of straw in all the small grains. Winter wheat matured early enough to escape the hot weather and drought which followed in July and August. Warm, dry, windy weather at the time spring grains should have been filling reduced their yields. The growth of corn was generally slow during the summer, but at no time did it appear to suffer from drought. The mild open fall permitted an average crop of good quality to mature. Frost-free period, 113 days.

Crop year 1921



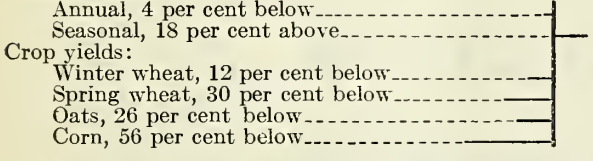
The fall of 1920 was so dry that winter wheat did not germinate until the spring of 1921. There was little reserve water in the soil. The rains of May and June were sufficient for the current needs of the crops but not to accumulate much reserve. Drought became critical at about heading time. By July 20 most of the corn was dried beyond recovery. Only a few of the plats produced any ears. Frost-free period, 118 days.

Crop year 1922



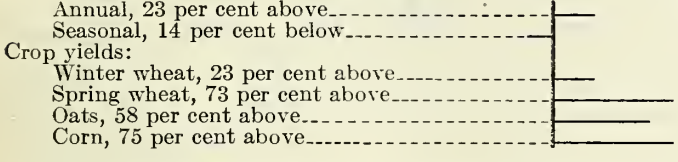
Rainfall was abundant and well distributed, and at no time during the growing season were the crops seriously affected by drought. The growth of straw was so heavy that lodging took place on many of the plats. Frost-free period, 146 days.

Crop year 1923



Late planting and a cool spring forced the filling of small grains into a drought period from June 27 to July 23. Corn suffered from drought at the same time to the extent that pollination was very poor. Frost-free period, 149 days.

Crop year 1924



Very favorable distribution of the rainfall throughout the growing season, cool weather, and an abundance of soil water accumulated during the previous fall combined to make this one of the best crop years in the history of the station. Frost-free period, 111 days.

RESULTS AT DICKINSON, N. DAK.

[Altitude, 2,453 feet; 18-year period (figs. 10 and 11)]

Climatic conditions: Mean annual precipitation, 16.05 inches; mean seasonal precipitation, 9.55 inches; mean seasonal evaporation, 32.516 inches.

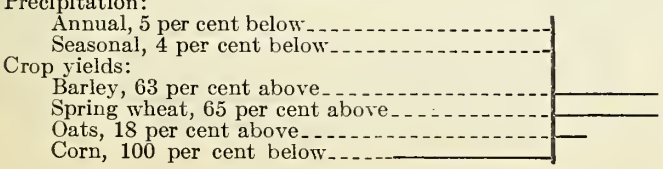
Average frost-free period, 113 days.

Soil: Sandy clay loam.

Number of crop yields averaged each year: Barley, 5; spring wheat, 25; oats, 27; corn, 23.

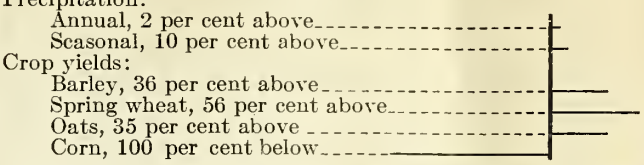
Average annual crop yields per acre: Barley, 24.6 bushels; spring wheat, 19.3 bushels; oats, 39.5 bushels; corn, 15.1 bushels.

Crop year 1907



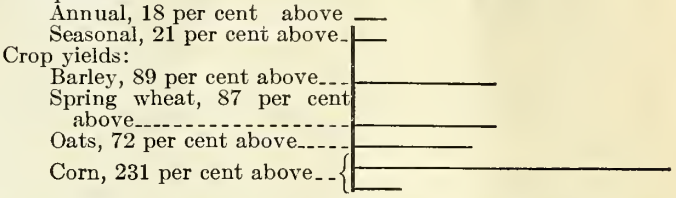
The crop of 1907 was the first crop on land broken about June 1, 1906, and cultivated during the summer. This treatment being equivalent to fallow, the crop had an unusual advantage of stored water. The average yield of oats was reduced about 20 per cent by a hailstorm on August 20, while they were being harvested. Corn did not mature. Frost-free period, 101 days.

Crop year 1908



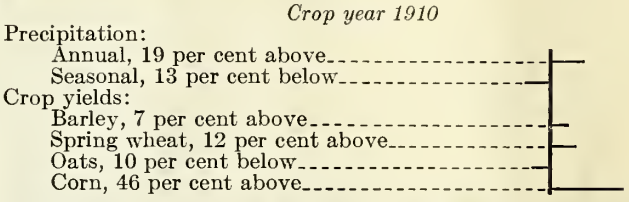
Corn was frosted before much of it reached the milk stage. Frost-free period, 92 days.

Crop year 1909



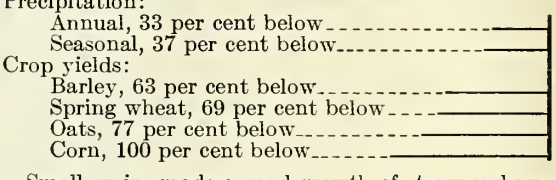
The yields of corn were the highest in the history of the station. Frost-free period, 147 days.

Crop year 1910



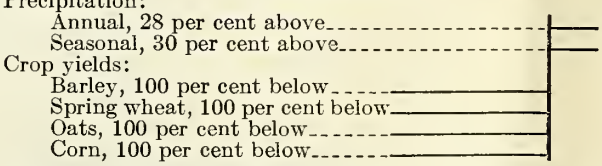
The yield of corn was well above the mean, but it was not well matured. Frost-free period, 95 days.

Crop year 1911



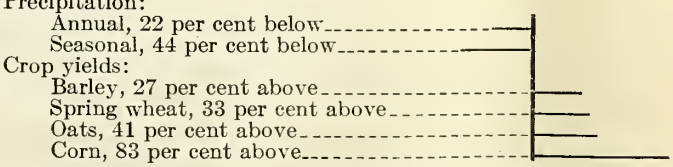
Small grains made a good growth of straw and were promising until the latter part of June. The July rainfall was deficient, and only those plats that were fallow in 1910 had sufficient water remaining in the soil to make a fair crop of grain. Corn was injured by the drought and was killed by frost August 27. Frost-free period, 92 days.

Crop year 1912



Very promising crop prospects were destroyed by hail on July 11. Frost-free period, 112 days.

Crop year 1913



The soil was well filled with water as cultivation began soon after the hailstorm early in July, 1912. All crops produced good yields. Frost-free period, 112 days.

MANDAN (N. DAK.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1913	4	.77	2.29	1.13	.16	.28	.07	.05	1.89	1.55	3.57	10.68	1.35	23.79	BARLEY	50.6	1914
	3														S.WHEAT	32.1	
	2														OATS	93.7	
	1														CORN	28.3	
1914	4	1.89	1.24	.90	.31	.37	.07	T	.30	1.11	4.98	6.32	6.48	23.97	BARLEY	52.3	1915
	3														S.WHEAT	35.1	
	2														OATS	74.6	
	1														CORN	27.0	
1915	4	.63	1.84	1.85	.34	.14	.28	.09	1.88	.93	1.69	2.25	3.55	15.47	BARLEY	27.5	1916
	3														S.WHEAT	20.5	
	2														OATS	55.9	
	1														CORN	37.1	
1916	4	2.04	.92	.27	.07	1.10	.28	.19	.35	1.87	.35	2.56	1.58	11.58	BARLEY	11.5	1917
	3														S.WHEAT	14.0	
	2														OATS	27.7	
	1														CORN	19.7	
1917	4	.89	1.97	.05	.03	.19	.20	.11	.45	2.61	2.45	.68	2.47	12.10	BARLEY	13.5	1918
	3														S.WHEAT	13.7	
	2														OATS	24.0	
	1														CORN	34.0	
1918	4	2.03	.63	.27	.45	1.02	.08	.80	.83	1.72	3.95	1.12	.85	13.75	BARLEY	8.8	1919
	3														S.WHEAT	11.0	
	2														OATS	23.7	
	1														CORN	24.0	
1919	4	1.22	.49	.98	1.19	.25	.52	.20	1.21	.58	1.72	1.85	2.68	12.89	BARLEY	5.7	1920
	3														S.WHEAT	5.6	
	2														OATS	12.4	
	1														CORN	6.7	
1920	4	1.81	1.29	.25	.37	.21	.18	.09	.79	2.59	3.05	.82	3.38	14.83	BARLEY	0.4	1921
	3														S.WHEAT	1.1	
	2														OATS	5.6	
	1														CORN	15.8	
1921	4	.25	1.58	1.39	.87	.24	.28	1.55	.52	.66	2.05	3.43	3.17	15.99	BARLEY	30.2	1922
	3														S.WHEAT	21.2	
	2														OATS	52.1	
	1														CORN	31.7	
1922	4	.32	2.31	.64	1.60	.82	.36	.38	.16	1.85	1.18	1.94	4.12	15.68	BARLEY	15.9	1923
	3														S.WHEAT	11.6	
	2														OATS	23.9	
	1														CORN	48.5	
1923	4	1.15	2.31	.54	.28	.14	.03	.25	.28	1.68	.41	5.56	2.07	14.70	BARLEY	23.6	1924
	3														S.WHEAT	22.1	
	2														OATS	49.6	
	1														CORN	46.2	
AVERAGE		1.18	1.53	.75	.52	.43	.21	.34	.79	1.56	2.31	3.38	2.88	15.88			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 12.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Mandan (N. Dak.) Field Station

Crop year 1914

Precipitation:
- Annual, 46 per cent above
- Seasonal, 73 per cent above

Crop yields:
- Barley, 8 per cent above
- Spring wheat, 20 per cent below
- Oats, 37 per cent below
- Corn, 26 per cent above

At the end of June, crop growth was exceptionally heavy. The heavy vegetation suffered some from drought in July. Destructive hail, rain, and wind on July 26 and 27 badly injured crops, the damage to oats being estimated at 50 per cent and to wheat at least 35 per cent. Barley was already in the shock. Corn matured without killing frost. Frost-free period, 144 days.

Crop year 1915

Precipitation:
- Annual, 20 per cent above
- Seasonal, 51 per cent above

Crop yields:
- Barley, 132 per cent above
- Spring wheat, 92 per cent above
- Oats, 136 per cent above
- Corn, 100 per cent below

The season was too short and cool for corn, and that crop did not mature. Frost-free period, 69 days.

Crop year 1916

Precipitation:
- Annual, 16 per cent above
- Seasonal, 18 per cent above

Crop yields:
- Barley, 22 per cent above
- Spring wheat, 21 per cent above
- Oats, 70 per cent above
- Corn, 18 per cent above

The yields of corn and the small grains, oats excepted, ranged from 18 to 22 per cent above their respective averages, while oat yields were 70 per cent above. Frost-free period, 62 days.

Crop year 1917

Precipitation:
- Annual, 26 per cent below
- Seasonal, 43 per cent below

Crop yields:
- Barley, 56 per cent below
- Spring wheat, 35 per cent below
- Oats, 55 per cent below
- Corn, 100 per cent below

Corn did not mature. Frost-free period, 69 days.

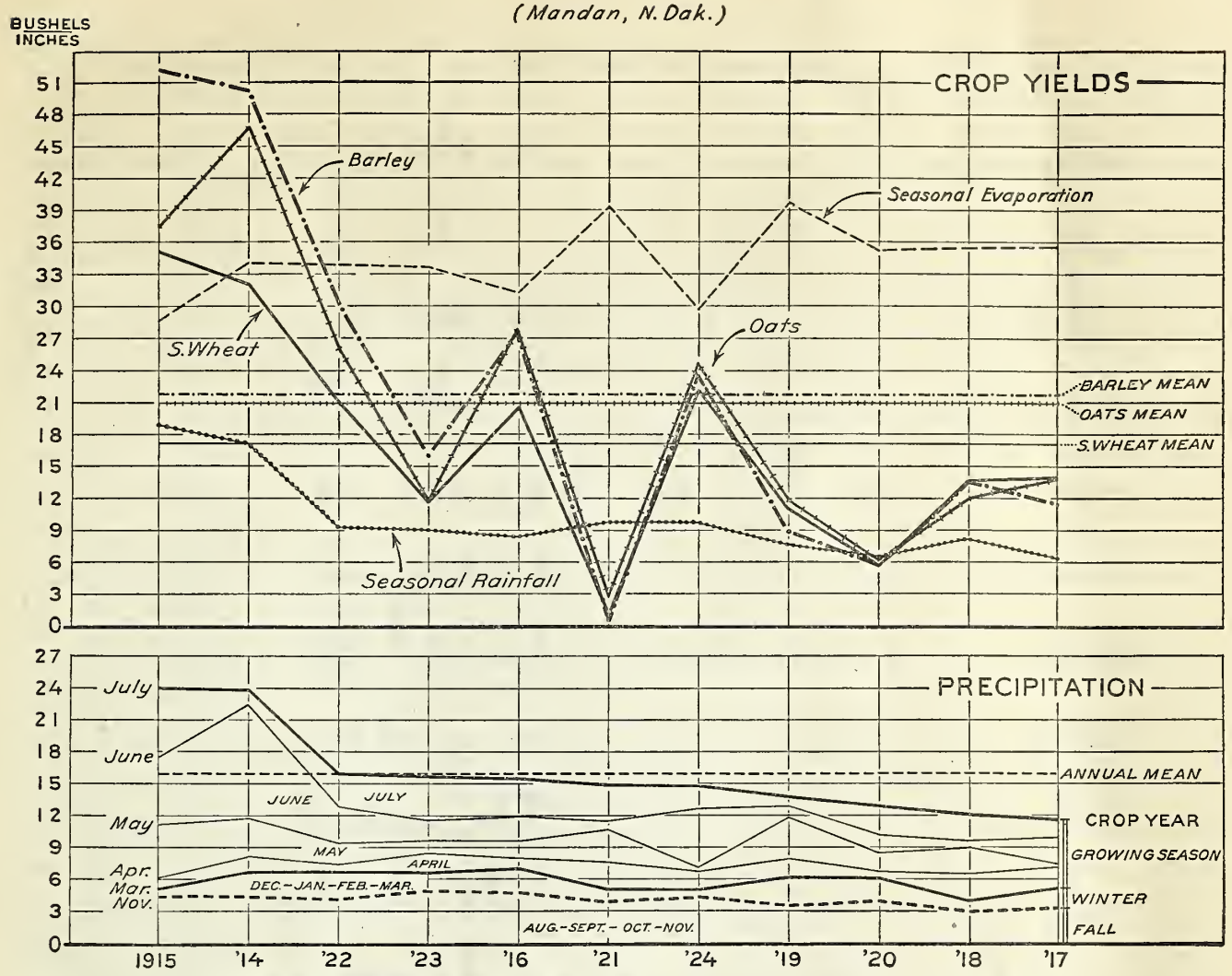


FIG. 13.—Diagram summarizing the relations between rainfall and crop yields at Mandan, N. Dak. (See text, p. 23).

Crop year 1918

Precipitation:
- Annual, 34 per cent below
- Seasonal, 25 per cent below

Crop yields:
- Barley, 85 per cent below
- Spring wheat, 52 per cent below
- Oats, 80 per cent below
- Corn, 100 per cent below

Corn did not mature. Frost-free period, 116 days.

Crop year 1919

Precipitation:
- Annual, 36 per cent below
- Seasonal, 52 per cent below

Crop yields:
- Barley, 95 per cent below
- Spring wheat, 80 per cent below
- Oats, 94 per cent below
- Corn, 36 per cent below

The drought continued for its third year. The season was the hottest and driest during the period for which records are available. The precipitation after May 11 was so scant that the yields of all crops except corn were the lowest in the station records (excepting 1912, when a good crop was destroyed by hail). Corn matured a crop, but it was below its 18-year average. Frost-free period, 124 days.

Crop year 1920

Precipitation:
- Annual, 21 per cent below
- Seasonal, 2 per cent below

Crop yields:
- Barley, 4 per cent above
- Spring wheat, 1 per cent below
- Oats, 2 per cent below
- Corn, 5 per cent below

From June 1 to July 22 the water supply was sufficient for the needs of small grain, and a heavy growth of straw was produced. Prospective yields suffered reduction by a hot wind on July 22 and an insufficient water supply after that date. Frost-free period, 155 days.

Crop year 1921

Precipitation:
- Annual, 10 per cent below
- Seasonal, 21 per cent below

Crops yields:
- Barley, 82 per cent below
- Spring wheat, 70 per cent below
- Oats, 72 per cent below
- Corn, 40 per cent below

Starting with an extremely dry soil in the spring, the seasonal precipitation was not sufficient for the needs of crops. The harvest of small grains was the earliest in the history of the station and the yields among the lowest. Corn matured, but the crop was light. Frost-free period, 137 days.

EDGELEY (N. DAK.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1905	4	1.71	.85	.24	1.46	T	.13	T	.16	1.58	5.59	3.69	3.17	18.58	BARLEY	31.2	1906
	3														S.WHEAT	30.9	
	2														OATS	61.4	
	1														CORN #	4912.0	
1906	4	1.56	1.45	.93	1.05	.65	.42	.06	.21	.35	2.23	1.76	2.10	12.77	BARLEY	12.9	1907
	3														S.WHEAT	9.1	
	2														OATS	24.9	
	1														CORN #	2420.0	
1907	4	1.20	2.79	.82	T	T	.04	.65	1.45	1.26	3.47	3.26	1.19	16.13	BARLEY	26.3	1908
	3														S.WHEAT	15.9	
	2														OATS	17.4	
	1														CORN #	2010.0	
1908	4	1.97	1.81	1.34	.63	.20	.12	.25	T	.63	4.56	1.97	3.24	16.72	BARLEY	29.2	1909
	3														S.WHEAT	27.6	
	2														OATS	56.0	
	1														CORN #	5042.0	
1909	4	1.87	1.00	.39	.34	.84	.14	.30	1.20	2.15	.30	1.91	.72	11.16	BARLEY	1.9	1910
	3														S.WHEAT	5.7	
	2														OATS	9.1	
	1														CORN #	1610.0	
1910	4	2.21	4.43	.15	.16	.10	.27	.35	.03	1.55	2.71	1.22	1.61	14.79	BARLEY	0.0	1911
	3														S.WHEAT	1.9	
	2														OATS	4.4	
	1														CORN #	4630.0	
1911	4	4.12	2.92	.67	.20	.41	.48	.01	.08	2.71	3.23	3.82	5.97	24.62	BARLEY	29.4	1912
	3														S.WHEAT	33.9	
	2														OATS	61.9	
	1														CORN #	6350.0	
1912	4	2.72	2.47	.04	T	.28	.31	.04	.24	1.46	1.44	3.98	2.65	15.63	BARLEY	24.2	1913
	3														S.WHEAT	22.6	
	2														OATS	40.7	
	1														CORN #	4268.0	
1913	4	3.74	2.90	3.37	.28	.25	.13	.20	.57	4.88	1.80	4.00	2.55	24.67	BARLEY	31.1	1914
	3														S.WHEAT	16.2	
	2														OATS	46.0	
	1														CORN #	4049.0	
1914	4	1.97	.80	.92	.10	.13	.21	.80	.20	1.36	4.47	4.87	3.11	18.94	BARLEY	41.5	1915
	3														S.WHEAT	36.0	
	2														OATS	79.7	
	1														CORN #	5900.0	
1915	4	1.61	2.23	2.78	.26	.30	.91	.16	1.59	1.23	4.16	2.91	4.18	22.32	BARLEY	21.5	1916
	3														S.WHEAT	8.8	
	2														OATS	22.5	
	1														CORN #	4525.0	
1916	4	2.98	1.02	.36	T	.79	.28	.45	.30	2.02	.22	3.08	2.22	13.72	BARLEY	10.3	1917
	3														S.WHEAT	14.2	
	2														OATS	16.4	
	1														CORN #	1840.0	
1917	4	.89	.89	.24	.10	.16	.17	.11	.10	2.95	1.21	1.21	3.21	11.24	BARLEY	11.3	1918
	3														S.WHEAT	15.4	
	2														OATS	19.6	
	1														CORN #	2879.0	
1918	4	2.47	.16	.38	1.03	.38	.10	.42	.73	1.27	4.07	4.64	3.47	19.12	BARLEY	13.8	1919
	3														S.WHEAT	2.2	
	2														OATS	16.2	
	1														CORN #	4382.0	
1919	4	.43	.35	1.18	.43	.29	.35	.02	.11	1.31	3.07	3.44	2.40	13.38	BARLEY	25.4	1920
	3														S.WHEAT	9.6	
	2														OATS	47.3	
	1														CORN #	2383.0	
1920	4	.58	2.93	.10	.05	.05	.10	.16	.99	1.69	3.31	5.76	2.61	18.33	BARLEY	17.8	1921
	3														S.WHEAT	14.8	
	2														OATS	29.6	
	1														CORN #	4364.0	
1921	4	1.27	4.01	.62	.30	.31	.45	1.05	.55	.76	4.02	2.44	1.34	17.12	BARLEY	--	1922
	3														S.WHEAT	22.9	
	2														OATS	34.9	
	1														CORN #	3452.0	
AVERAGE		1.96	1.94	.85	.38	.30	.27	.30	.50	1.72	2.93	3.17	2.69	17.01			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	# Corn fodder in pounds		

FIG. 14.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Edgeley (N. Dak.) Field Station

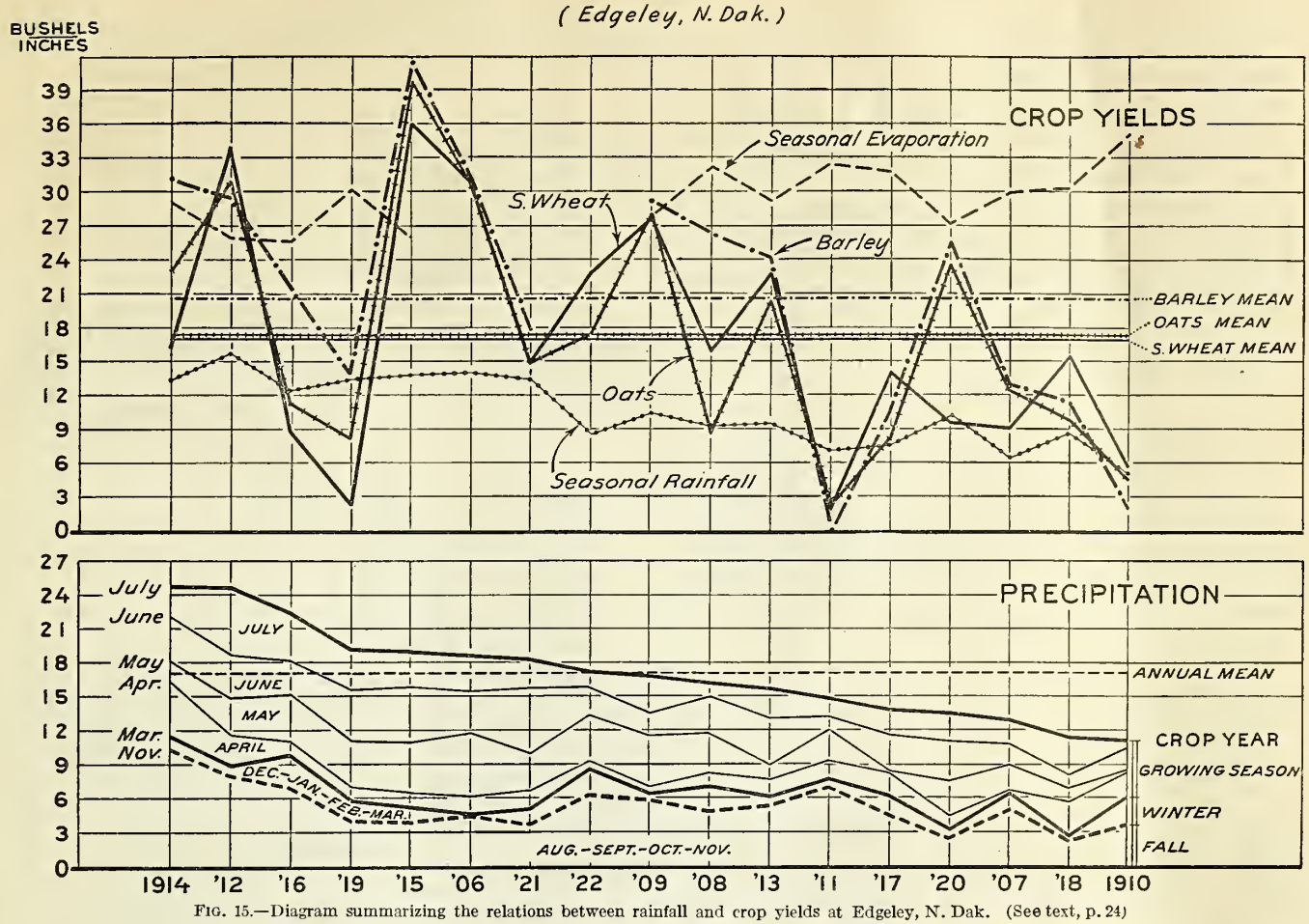


FIG. 15.—Diagram summarizing the relations between rainfall and crop yields at Edgeley, N. Dak. (See text, p. 24)

Crop year 1922

Precipitation:
- Annual, 24 per cent above
- Seasonal, 21 per cent above

Crop yields:
- Barley, 77 per cent above
- Spring wheat, 55 per cent above
- Oats, 85 per cent above
- Corn, 68 per cent above

The feature of the season was the heavy June rainfall. Although the precipitation in July and August was below the normal for those months, there was enough water available to mature a crop above the average. Frost-free period, 165 days.

Crop year 1923

Precipitation:
- Annual, 12 per cent above
- Seasonal, 28 per cent above.

Crop yields:
- Barley, 13 per cent above
- Spring wheat, 6 per cent below
- Oats, 16 per cent above
- Corn, 221 per cent above

Few special features characterized the year of 1923. Crop conditions were better than the average, and the yields of all crops except wheat were above their averages. The yield of corn was nearly a record breaker, being exceeded only in 1909. Grain crops were injured some by drying high winds during the middle of June. Frost-free period, 120 days.

Crop year 1924

Precipitation:
- Annual, 3 per cent above
- Seasonal, 13 per cent below

Crop yields:
- Barley, mean.
- Spring wheat, 12 per cent above
- Oats, 53 per cent above
- Corn, 88 per cent above

The season in general was cool. Grain yields were above the average, as a result of an unusual supply of water in the soil at the beginning of the season and cool weather during the ripening period. Corn was delayed by the cool season so that only 25 per cent of it matured. The yields of wheat were reduced by root-rot and those of barley by some similar disease. Frost-free period, 125 days.

RESULTS AT MANDAN, N. DAK.

[Altitude, 1,644 feet; 11-year period (figs. 12 and 13)]

Climatic conditions: Mean annual precipitation, 15.88 inches; mean seasonal precipitation, 10.13 inches; mean seasonal evaporation, 34.211 inches.

Average frost-free period, 133 days.

Soil: Sandy loam, bench land about 100 feet above Heart River. Duplicate plats on heavy clay, glacial till.

Number of crop yields averaged each year: Spring wheat, 67; oats, 66; barley, 23; corn, 60.

Average annual crop yields per acre: Spring wheat, 17.1 bushels; oats, 40.3 bushels; barley, 21.8 bushels; corn, 29 bushels.

Crop year 1914

Precipitation:
- Annual, 50 per cent above
- Seasonal, 69 per cent above

Crop yields:
- Spring wheat, 88 per cent above
- Oats, 133 per cent above
- Barley, 132 per cent above
- Corn, 2 per cent below

The crop of 1914 was the first one grown on the station and was on land broken early in 1913. The season was exceptionally favorable to plant growth and development. The precipitation was abnormally high. The rainfall of 10.68 inches in June is the highest ever recorded here for a single month. Frost-free period, 104 days.

Crop year 1915

Precipitation:
- Annual, 51 per cent above
- Seasonal, 86 per cent above

Crop yields:
- Spring wheat, 105 per cent above
- Oats, 85 per cent above
- Barley, 139 per cent above
- Corn, 7 per cent below

Low temperatures prevailed during the growing season. It was characterized as very favorable to crops in general throughout the State, with yields the most bountiful in its history. The yield of corn was good, but the season was too cool for the best results with that crop. Frost-free period, 138 days.

Crop year 1916

Precipitation:
- Annual, 3 per cent below
- Seasonal, 17 per cent below

Crop yields:
- Spring wheat, 20 per cent above
- Oats, 38 per cent above
- Barley, 26 per cent above
- Corn, 28 per cent above

Crops did not suffer materially for water at any time during the season. Hot weather when small grains were filling undoubtedly reduced their yields somewhat, but was beneficial to corn. Frost-free period, 122 days.

Crop year 1917

Precipitation:
- Annual, 27 per cent below
- Seasonal, 37 per cent below

Crop yields:
- Spring wheat, 18 per cent below
- Oats, 31 per cent below
- Barley, 47 per cent below
- Corn, 32 per cent below

The season was one of very low precipitation, with extremely hot weather during the growing period. The production of fair yields was attributed to the facts that the seasonal rainfall was supplemented to some extent by water stored in the soil and that the early dry weather tended to check the development of heavy vegetative growth. Frost-free period, 122 days.

Crop year 1918

Precipitation:
- Annual, 24 per cent below
- Seasonal, 19 per cent below

Crop yields:
- Spring wheat, 20 per cent below
- Oats, 40 per cent below
- Barley, 38 per cent below
- Corn, 17 per cent above

The season was without as much hot weather as 1917. The behavior of the crops was much the same as in 1917. The yield of corn was somewhat better, as it was especially benefited by the rains that came in the latter part of July. Frost-free period, 131 days.

Crop year 1919

Precipitation:
- Annual, 13 per cent below
- Seasonal, 25 per cent below

Crop yields:
- Spring wheat, 36 per cent below
- Oats, 41 per cent below
- Barley, 60 per cent below
- Corn, 17 per cent below

The season opened quite favorably, with good rains in April and during the first half of May, providing plenty of water for the immediate needs of all crops. After the middle of May the weather turned hot and dry and continued so throughout the summer. High south winds were frequent. With no reserve water in the soil for crops to draw on, their yields were light. Frost-free period, 123 days.

Crop year 1920

Precipitation:
- Annual, 19 per cent below
- Seasonal, 33 per cent below

Crop yields:
- Spring wheat, 67 per cent below
- Oats, 69 per cent below
- Barley, 74 per cent below
- Corn, 77 per cent below

The season opened with conditions favorable to starting practically all crops, but with no reserve of water in the soil except in fallow. Frost-free period, 154 days.

Crop year 1921

Precipitation:
- Annual, 7 per cent below
- Seasonal, 3 per cent below

Crop yields:
- Spring wheat, 94 per cent below
- Oats, 86 per cent below
- Barley, 98 per cent below
- Corn, 45 per cent below

The worst crop failures in the history of the station were recorded. A shortage of rainfall in June and high temperatures during the last few days of the month blighted most grains so severely that but little development took place thereafter. Drought became apparent about the middle of June and was not effectually broken until July 25. Corn tasseled during this period and the set of ears was poor. Frost-free period, 139 days.

Crop year 1922

Precipitation:
- Annual, 1 per cent above
- Seasonal, 8 per cent below

Crop yields:
- Spring wheat, 24 per cent above
- Oats, 29 per cent above
- Barley, 39 per cent above
- Corn, 9 per cent above

The precipitation did not differ materially in total amount for either the season or the crop year from that in 1921, but a better distribution, together with more moderate temperatures and lower evaporation, made it much more efficient. Small grains were retarded in April and May, but were brought back to normal by the rainfall of June and July. The maturity of corn was hastened and its yield reduced by drought in August. Frost-free period, 165 days.

Crop year 1923

Precipitation:
- Annual, 1 per cent below
- Seasonal, 10 per cent below

Crop yields:
- Spring wheat, 32 per cent below
- Oats, 41 per cent below
- Barley, 27 per cent below
- Corn, 67 per cent above

During May and June the precipitation was below normal and the yields of small grains were reduced below their respective averages and below the yields of 1922. The precipitation for July was above normal, and the yield of corn was the highest obtained at this station. The yield of wheat was somewhat reduced by rust. Frost-free period, 143 days.

Crop year 1924

Precipitation:
- Annual, 7 per cent below
- Seasonal, 4 per cent below

Crop yields:
- Spring wheat, 29 per cent above
- Oats, 23 per cent above
- Barley, 8 per cent above
- Corn, 59 per cent above

The season of 1924 was one of the most favorable to crop production that the Missouri slope had experienced for a number of years. The rather late, cool season and a high June rainfall allowed all crops to produce high yields. Frost-free period, 125 days.

RESULTS AT EDGELEY, N. DAK.

[Altitude, 1,561 feet; 17-year period (figs. 14 and 15)]

Climatic conditions: Mean annual precipitation, 17.01 inches; mean seasonal precipitation, 10.51 inches; mean seasonal evaporation, 29.482 inches.

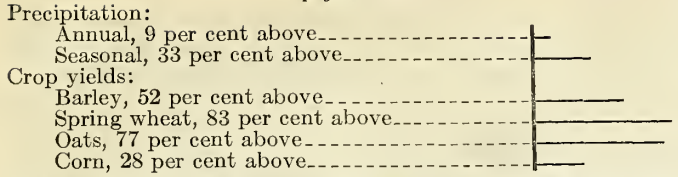
Average frost-free period, 126 days.

Soil: Clay loam of glacial origin overlying decomposed Pierre shale.

Number of crop yields averaged each year: Barley, 5; spring wheat, 28; oats, 28; corn, 25.

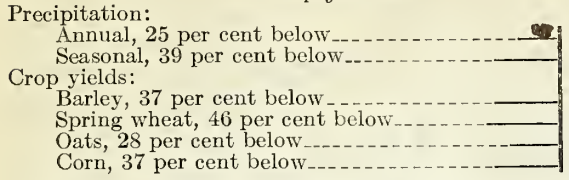
Average annual crop yields per acre: Barley, 20.5 bushels; spring wheat, 16.9 bushels; oats, 34.6 bushels; corn, 3,825 pounds.

Crop year 1906



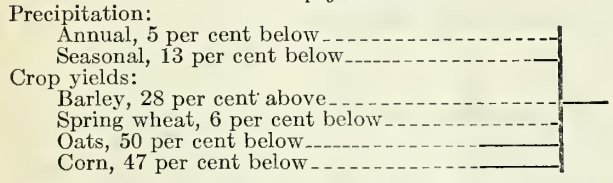
As a rule, all crops made good stands and ripened uniformly. Corn ripened early enough to escape killing frosts and made a good yield for the section. Frost-free period, 131 days.

Crop year 1907



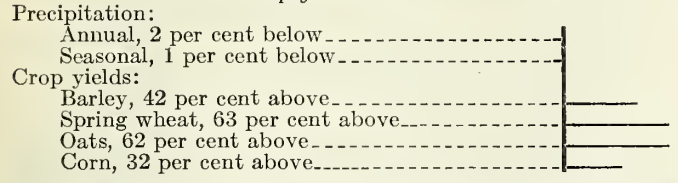
There was little rain during the growing season. Just previous to ripening time hot dry winds injured the small grains. A hailstorm on July 13 did some damage to small grains and hurt the corn very appreciably. No ears were matured on the corn. Frost-free period, 85 days.

Crop year 1908



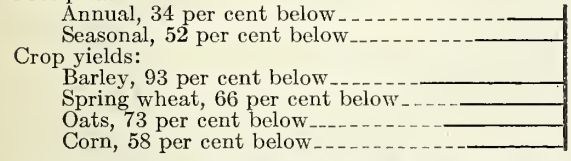
The spring was cold, with late freezes, and stands especially of oats were poor and spotted. Growth in June was good, but dry hot weather from about July 10 until harvest reduced yields. The relatively poor yield of oats was due to the greater injury done it by the spring freezes and the hot winds preceding harvest. The relatively high yield of barley was due to its earlier maturity. Corn was nearly a failure. The stand was poor, and late replanting was necessary. A hailstorm on August 11 stripped the leaves from the corn and nearly stopped all further growth. No ears matured. Frost-free period, 143 days.

Crop year 1909



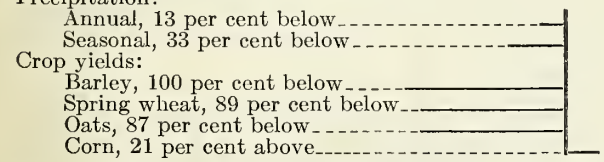
The prospective yields of small grains were decreased somewhat by hot dry winds just before the middle of July. Corn was mature September 9. Frost-free period, 137 days.

Crop year 1910



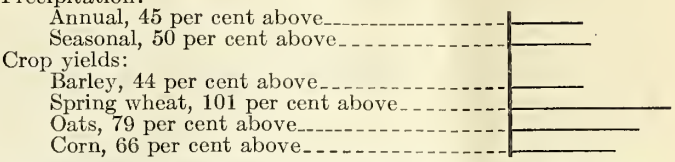
The crops were injured and their early growth checked by cold weather and heavy frosts after they came up in the spring. Only nubbins set on the corn, and these did not develop. Frost-free period, 102 days.

Crop year 1911



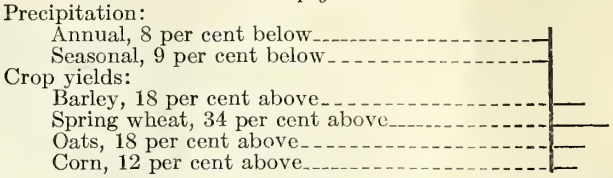
The rainfall was poorly distributed, with particularly marked deficiency in June and July. The heavy rainfall of August enabled corn to make a fairly good crop of fodder, but only a few ears matured. Frost-free period, 143 days.

Crop year 1912



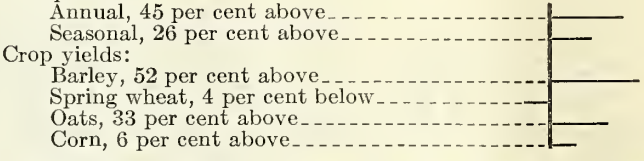
Temperatures and evaporation were low, and the precipitation was more than sufficient for the needs of the crops. At no time did they suffer from a lack of water. The season was too cool to mature corn. Frost-free period, 132 days.

Crop year 1913



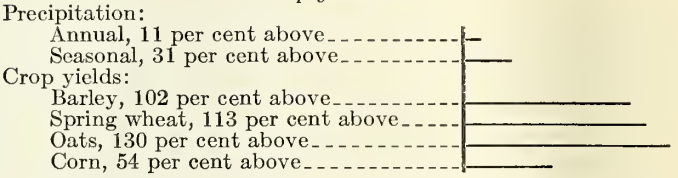
Small grains suffered from a lack of water in the first half of June and again in the latter part of July and the first of August. Corn matured on all the plats. Frost-free period, 107 days.

Crop year 1914



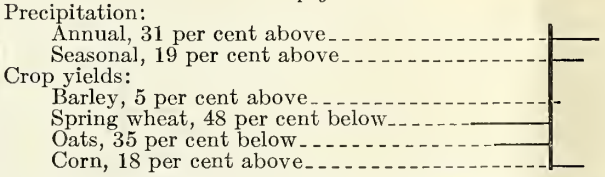
Yields were reduced by drought, rust, and hail in the period immediately preceding harvest. The greatest damage from hail was suffered by oats and corn, and from rust by wheat. Frost-free period, 133 days.

Crop year 1915



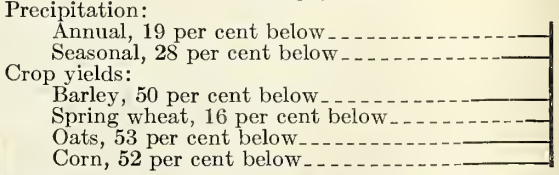
The spring was dry, but at no time after May 1 was there any suffering from a lack of water. There was some lodging and rust in wheat and oats, but yields were the highest obtained at the station. Corn eared well, but did not mature. Frost-free period, 120 days.

Crop year 1916



The low yields and poor quality of wheat and oats were the result of rust which developed in July with warm humid weather. At no time was there a lack of water. Corn made a good yield of fodder and matured some grain. Frost-free period, 135 days.

Crop year 1917



Crops suffered more or less continuously from drought, and yields were low. Corn matured no ears and made only a light yield of fodder. Frost-free period, 106 days.

SHERIDAN (WYO.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1916	4	.13	.56	2.85	.90	1.07	.84	37	1.31	.63	3.84	1.36	.09	13.95	W.WHEAT	9.2	1917
	3														S.WHEAT	5.5	
	2														OATS	23.6	
	1														CORN	11.1	
1917	4	.43	.08	1.02	.08	.78	1.56	.08	1.65	2.92	3.18	1.54	1.16	14.48	W.WHEAT	34.8	1918
	3														S.WHEAT	24.8	
	2														OATS	57.4	
	1														CORN	32.2	
1918	4	1.02	2.60	.80	.60	.15	.26	.23	.21	.94	1.01	1.12	.77	9.71	W.WHEAT	1.9	1919
	3														S.WHEAT	1.6	
	2														OATS	0.4	
	1														CORN	0.0	
1919	4	.30	1.16	1.80	.62	.14	.46	.38	.49	2.35	2.68	3.11	1.11	14.60	W.WHEAT	28.0	1920
	3														S.WHEAT	23.6	
	2														OATS	52.0	
	1														CORN	17.3	
1920	4	.56	.45	1.13	.60	.32	.44	.02	.65	.94	2.08	2.63	1.41	11.23	W.WHEAT	10.3	1921
	3														S.WHEAT	6.3	
	2														OATS	8.1	
	1														CORN	0.6	
1921	4	.30	.35	.21	1.38	.20	1.27	.19	.35	2.63	2.82	3.48	3.12	16.30	W.WHEAT	27.1	1922
	3														S.WHEAT	29.5	
	2														OATS	48.9	
	1														CORN	23.0	
1922	4	1.27	.15	1.26	.82	.59	.41	.22	1.34	2.37	1.95	2.94	3.45	16.77	W.WHEAT	17.7	1923
	3														S.WHEAT	21.6	
	2														OATS	46.4	
	1														CORN	38.9	
1923	4	.85	9.35	1.54	.43	.33	.30	1.10	1.06	1.63	1.56	2.12	.98	21.25	W.WHEAT	45.5	1924
	3														S.WHEAT	23.3	
	2														OATS	55.1	
	1														CORN	25.3	
AVERAGE		.61	1.84	1.33	.68	.45	.69	.32	.88	1.80	2.39	2.29	1.51	14.79			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 16.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Sheridan (Wyo.) Field Station

Crop year 1918

Precipitation:
- Annual, 33 per cent below
- Seasonal, 18 per cent below

Crop yields:
- Barley, 45 per cent below
- Spring wheat, 9 per cent below
- Oats, 43 per cent below
- Corn, 25 per cent below

The comparatively low yields were the result of drought prior to July 20. Corn suffered again from a lack of water in the latter part of August. Frost-free period, 105 days.

Crop year 1919

Precipitation:
- Annual, 12 per cent above
- Seasonal, 28 per cent above

Crop yields:
- Barley, 33 per cent below
- Spring wheat, 87 per cent below
- Oats, 53 per cent, below
- Corn, 15 per cent above

There was some damage from drought and high temperatures, but rust was chiefly responsible for the low yields of wheat and oats. Frost-free period, 142 days.

Crop year 1920

Precipitation:
- Annual, 21 per cent below
- Seasonal, 3 per cent, below

Crop yields:
- Barley, 24 per cent above
- Spring wheat, 43 per cent below
- Oats, 37 per cent above
- Corn, 38 per cent below

Wheat was badly damaged by rust, the loss being estimated at 50 per cent. Corn suffered from drought in the latter part of its season. Frost-free period, 138 days.

Crop year 1921

Precipitation:
- Annual, 8 per cent above
- Seasonal, 27 per cent above

Crop yields:
- Barley, 13 per cent below
- Spring wheat, 12 per cent below
- Oats, 14 per cent below
- Corn, 14 per cent above

Ideal growing weather prevailed until July 9. Hot dry weather with high winds from that time until July 27 damaged small grains and prevented corn from earing. Frost-free period, 141 days.

Crop year 1922

Precipitation:
- Annual, 1 per cent above
- Seasonal, 19 per cent below

Crop yields:
- Barley (no record).
- Spring wheat, 35 per cent above
- Oats, 1 per cent above
- Corn, 10 per cent below

The yield of oats was reduced by rust. Corn suffered badly during the greater part of August from a lack of water. Many of the stalks did not ear at all, and those that did produced only small nubbins. Frost-free period, 134 days.

RESULTS AT SHERIDAN, WYO.

[Altitude, 3,724 feet; 8-year period (figs. 16 and 17)]

Climatic conditions: Mean annual precipitation, 14.79 inches; mean seasonal precipitation, 7.99 inches; mean seasonal evaporation, 34.212 inches.

Average frost-free period, 131 days.

Soil: Clay loam.

Number of crop yields averaged each year: Winter wheat, 23; spring wheat, 37; oats, 50; corn, 44.

Average annual crop yields per acre: Winter wheat, 21.8 bushels; spring wheat, 17 bushels; oats, 36.5 bushels; corn, 18.6 bushels.

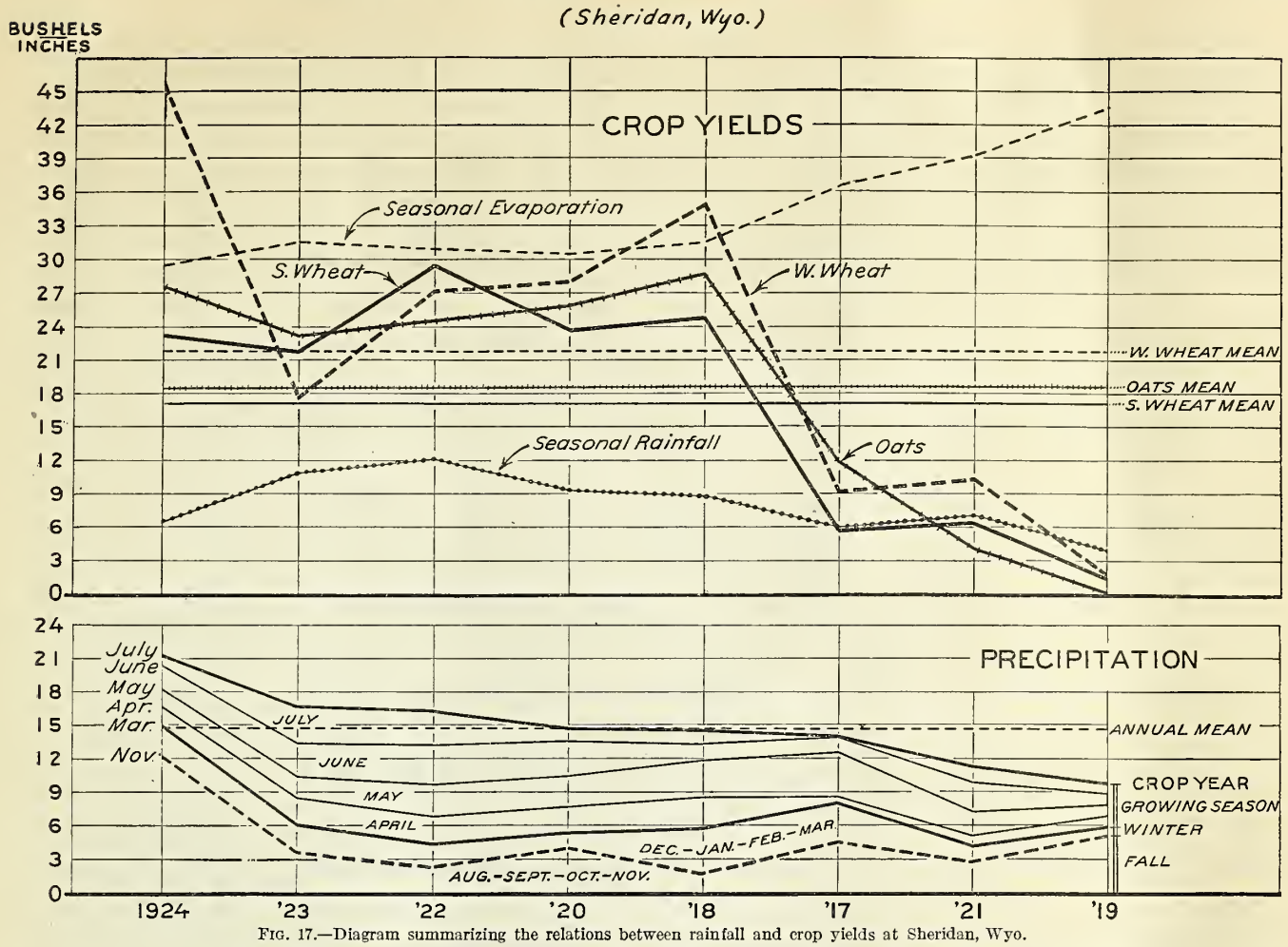


FIG. 17.—Diagram summarizing the relations between rainfall and crop yields at Sheridan, Wyo.

Crop year 1917

Precipitation:
- Annual, 6 per cent below
- Seasonal, 26 per cent below

Crop yields:
- Winter wheat, 58 per cent below
- Spring wheat, 68 per cent below
- Oats, 35 per cent below
- Corn, 40 per cent below

Crop prospects were very bright until about July 1, when a drought that began June 11 was much in evidence. The drought was not broken by rain of consequence until October 20. Frost-free period, 129 days.

Crop year 1918

Precipitation:
- Annual, 2 per cent below
- Seasonal, 10 per cent above

Crop yields:
- Winter wheat, 60 per cent above
- Spring wheat, 46 per cent above
- Oats, 57 per cent above
- Corn, 73 per cent above

Frequent rains during April kept the soil so wet that no team work could be done on it until the 29th. The soil was then wet to a depth of about 3 feet. With this reserve in the soil the precipitation during the growing season was sufficient to develop all crops normally with little or no suffering from drought, and the yields were among the best in the history of the station. Frost-free period, 144 days.

Crop year 1919

Precipitation:
- Annual, 34 per cent below
- Seasonal, 52 per cent below

Crop yields:
- Winter wheat, 92 per cent below
- Spring wheat, 92 per cent below
- Oats, 99 per cent below
- Corn, 100 per cent below

Small grains began to suffer from drought early in June and from heat and drought the last 10 days in June, and conditions were not relieved until they were either harvested or dried up and died. Corn began to suffer from drought at the tasseling stage about the middle of July. Frost-free period, 129 days.

Crop year 1920

Precipitation:
- Annual, 1 per cent below
- Seasonal, 16 per cent above

Crop yields:
- Winter wheat, 28 per cent above
- Spring wheat, 39 per cent above
- Oats, 42 per cent above
- Corn, 7 per cent below

The spring was rather backward, the ground being very wet from the fall rains and the winter snow. Cool weather with frequent rain or snow during April and May made field work difficult and slow. There was plenty of water until after the middle of July. The small grains did not mature until August and were shrunken considerably by hot weather and a lack of water during the ripening period. Corn was drying badly when it was frosted on August 29. It was not fully matured. Frost-free period, 125 days.

Crop year 1921

Precipitation:
- Annual, 24 per cent below
- Seasonal, 12 per cent below

Crop yields:
- Winter wheat, 53 per cent below
- Spring wheat, 63 per cent below
- Oats, 78 per cent below
- Corn, 97 per cent below

Even fair yields of grain were produced only on land that was fallowed in 1920. Except on land so treated there was but little water in the soil in the spring. Sufficient rain fell early in the season to give all crops a fair start, but the effects of drought and hot weather were evident on many plats by the middle of

BELLEFOURCHE (S. DAK.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1907	4	1.07	2.13	T	T	.44	.20	.19	1.65	1.16	3.95	1.47	1.26	13.52	W.WHEAT		1908
	3														S.WHEAT	21.7	
	2														OATS	32.4	
	1														CORN		
1908	4	.62	.52	2.03	.20	.91	.17	.23	.19	.84	3.87	5.59	2.45	17.62	W.WHEAT	28.9	1909
	3														S.WHEAT	28.7	
	2														OATS	60.9	
	1														CORN	19.3	
1909	4	.55	1.07	.76	.73	1.28	.73	.70	.93	1.57	1.26	1.51	1.42	12.51	W.WHEAT	1.8	1910
	3														S.WHEAT	2.6	
	2														OATS	6.8	
	1														CORN	0.6	
1910	4	1.03	2.92	.27	.11	.10	.13	.05	.09	.17	.45	.50	.80	6.62	W.WHEAT	0.0	1911
	3														S.WHEAT	0.0	
	2														OATS	0.0	
	1														CORN	0.0	
1911	4	1.86	.92	.39	.98	.30	.24	.10	.71	2.32	2.26	.29	3.20	13.57	W.WHEAT	0.0	1912
	3														S.WHEAT	0.0	
	2														OATS	8.2	
	1														CORN	21.9	
1912	4	2.80	3.49	.51	.04	.13	.57	.24	.99	.25	1.98	3.10	35	14.45	W.WHEAT	21.3	1913
	3														S.WHEAT	10.8	
	2														OATS	23.9	
	1														CORN	8.6	
1913	4	.26	2.38	1.86	.10	.45	T	1.00	.29	1.09	2.22	2.09	1.34	13.08	W.WHEAT	18.2	1914
	3														S.WHEAT	10.1	
	2														OATS	26.3	
	1														CORN	0.5	
1914	4	1.12	.35	1.77	.00	.43	.92	1.01	.16	2.58	2.32	4.74	5.74	21.14	W.WHEAT	36.2	1915
	3														S.WHEAT	57.6	
	2														OATS	125.6	
	1														CORN	44.5	
1915	4	.44	1.26	1.25	.43	.17	.36	.23	.98	.64	3.17	2.19	2.01	13.13	W.WHEAT	12.7	1916
	3														S.WHEAT	17.3	
	2														OATS	33.3	
	1														CORN	32.5	
1916	4	2.02	.20	.99	.33	.28	.92	.74	.27	2.51	3.71	.97	.80	13.74	W.WHEAT	3.8	1917
	3														S.WHEAT	7.4	
	2														OATS	17.1	
	1														CORN	20.4	
1917	4	1.67	.35	.46	T	.92	.99	.64	.81	2.40	1.60	1.17	3.41	14.42	W.WHEAT	27.1	1918
	3														S.WHEAT	11.9	
	2														OATS	23.3	
	1														CORN	30.0	
1918	4	2.99	3.08	.22	.15	.85	.04	.57	.87	2.14	1.14	.35	2.59	14.99	W.WHEAT	2.0	1919
	3														S.WHEAT	0.9	
	2														OATS	2.3	
	1														CORN	0.3	
1919	4	1.02	1.20	2.49	1.22	.62	.65	.16	1.35	2.59	8.35	5.90	2.53	28.08	W.WHEAT	1.6	1920
	3														S.WHEAT	29.9	
	2														OATS	63.8	
	1														CORN	37.4	
1920	4	.56	.63	1.67	.55	.95	.29	T	.84	.72	1.44	3.36	2.30	13.31	W.WHEAT	5.4	1921
	3														S.WHEAT	7.3	
	2														OATS	11.6	
	1														CORN	9.0	
1921	4	.52	.72	.10	.30	.50	1.31	.38	.20	2.84	3.42	3.74	6.52	20.55	W.WHEAT	30.8	1922
	3														S.WHEAT	32.2	
	2														OATS	66.0	
	1														CORN	42.3	
1922	4	.90	T	.79	2.82	.24	.22	.23	.32	.82	2.31	3.81	4.54	17.00	W.WHEAT	21.3	1923
	3														S.WHEAT	28.0	
	2														OATS	57.5	
	1														CORN	52.4	
1923	4	5.35	5.95	3.14	.27	.41	.08	.88	.70	.81	.68	1.27	1.22	20.76	W.WHEAT	30.5	1924
	3														S.WHEAT	21.5	
	2														OATS	44.1	
	1														CORN	17.7	
AVERAGE		1.46	1.60	1.10	.48	.53	.46	.43	.67	1.50	2.60	2.47	2.50	15.80			
MONTH		AUG.	SEPT.	OCT.	NOV	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 18.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Bellefourche (S. Dak.) Field Station

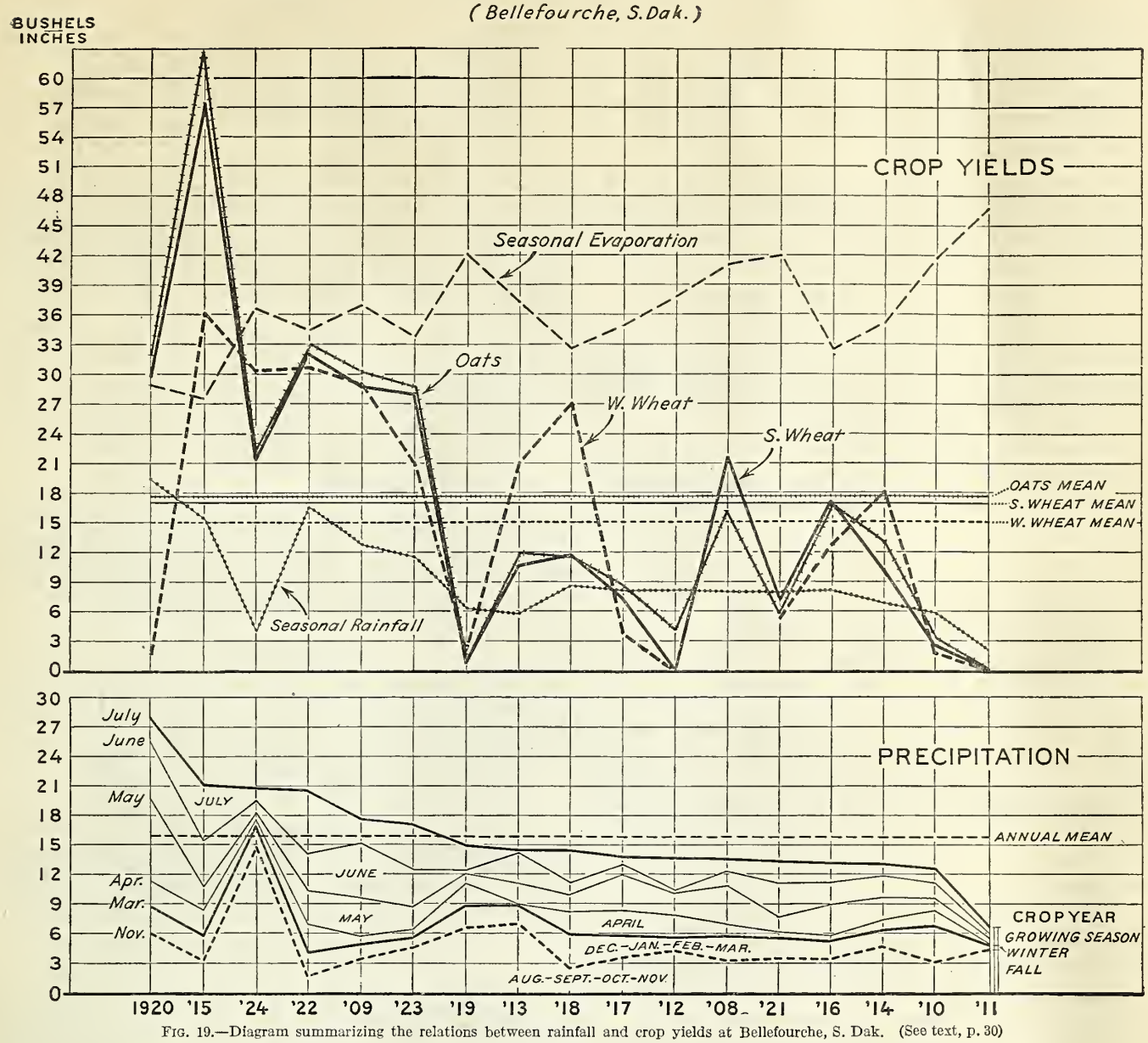


FIG. 19.—Diagram summarizing the relations between rainfall and crop yields at Bellefourche, S. Dak. (See text, p. 30)

June. The rainfall for the remainder of the season was not sufficient for the needs of growing crops. The heavier precipitation came in dashing showers from which there was considerable run-off. Some damage was done by grasshoppers that came in from the surrounding grassland. Frost-free period, 121 days.

Crop year 1922

Precipitation:
- Annual, 10 per cent above
- Seasonal, 51 per cent above

Crop yields:
- Winter wheat, 24 per cent above
- Spring wheat, 74 per cent above
- Oats, 34 per cent above
- Corn, 24 per cent above

Crops did not suffer severely from a lack of water at any time during the season. Good yields were produced by nearly all methods of preparation. The relatively low yield of winter wheat in comparison with spring wheat was due to unfavorable fall conditions, as a result of which it did not emerge until spring and then with a rather poor stand. The prospective yields of both oats and corn were considerably reduced by a hail and wind storm July 23. Frost-free period, 141 days.

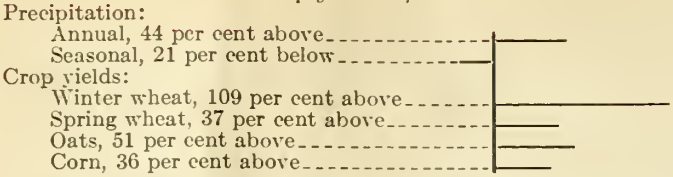
Crop year 1923

Precipitation:
- Annual, 13 per cent above
- Seasonal, 34 per cent above

Crop yields:
- Winter wheat, 19 per cent below
- Spring wheat, 27 per cent above
- Oats, 27 per cent above
- Corn, 109 per cent above

There was more than the usual contrast in the results from different methods of tillage, yields ranging from poor to very good with the grain crops. The yields of corn and all forage crops were good. The average yield of winter wheat was good, although it was below the normal. Small grains suffered from drought at times during June and July. The heads were not well filled and the quality of the grain was not as good as usual. The heavy rainfall of the latter part of July came too late to benefit small grains, but provided ample water for corn and other late crops for which the water supply had been sufficient. Grasshoppers were present in large numbers and did some damage to all crops. Frost-free period, 149 days.

Crop year 1924



The precipitation during the growing season was light, but the fall rains in 1923 were exceptionally heavy, and in the spring the soil was wet to the full depth sampled, 6 feet. Corn suffered somewhat from a lack of readily available water in its later stages of growth. Frost-free period, 110 days.

RESULTS AT BELLEFOURCHE, S. DAK.

[Altitude, 2,875 feet; 17-year period (figs. 18 and 19)]

Climatic conditions: Mean annual precipitation, 15.80 inches; mean seasonal precipitation, 9.07 inches; mean seasonal evaporation, 36.543 inches.

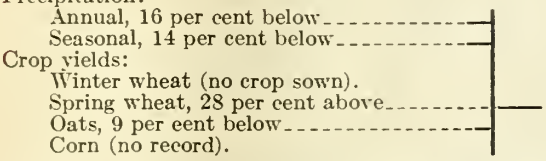
Average frost-free period, 137 days.

Soil: "Gumbo," decomposed Pierre shale.

Number of crop yields averaged each year: Winter wheat, 6; spring wheat, 30; oats, 32; corn, 27.

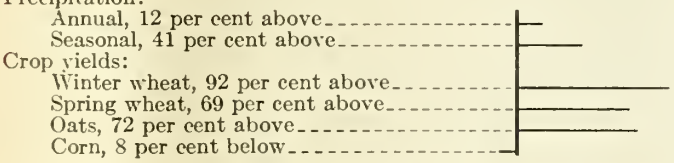
Average annual crop yields per acre: Winter wheat, 15.1 bushels; spring wheat, 16.9 bushels; oats, 35.5 bushels; corn, 21.1 bushels.

Crop year 1908



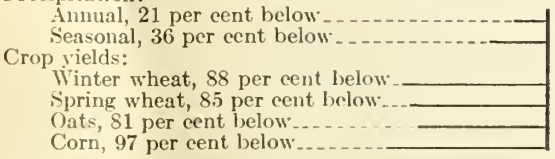
The crop of 1908 was the first one on the station and was grown on land broken in 1907. This preparation was equivalent to fallow. The greater yield of wheat in comparison with oats was undoubtedly due to the fact that it was earlier and consequently suffered less from the July drought. Corn had a good growth of stalks but few ears. Frost-free period, 128 days.

Crop year 1909



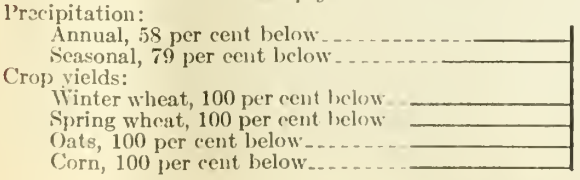
Corn made a fair crop, but dry weather late in the season cut its yield below the average. Frost-free period, 128 days.

Crop year 1910



The low yields were the result of drought. Frost-free period, 124 days.

Crop year 1911

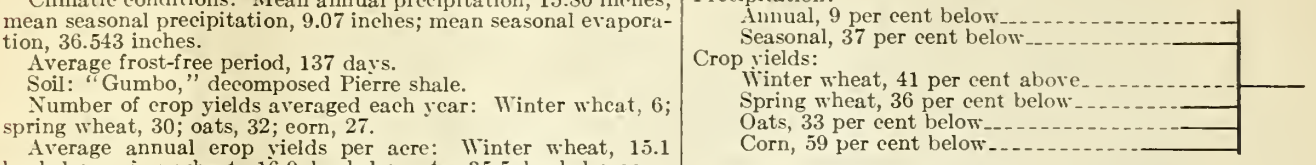


The year was the driest in the history of the station, and all crops failed completely. Frost-free period, 144 days.

Crop year 1912

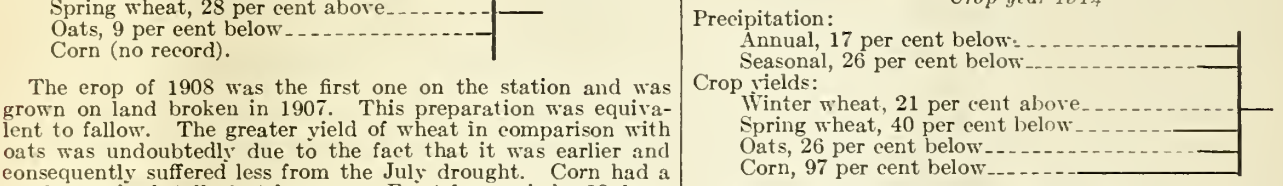
There was no stand of winter wheat, and it was reseeded to spring wheat. The rains in the first week of July came too late to save wheat, which had been injured beyond recovery by the drought that started in the latter part of May and continued throughout June. Oats and barley survived sufficiently to produce some grain. Corn made a crop slightly above the average. Frost-free period, 155 days.

Crop year 1913



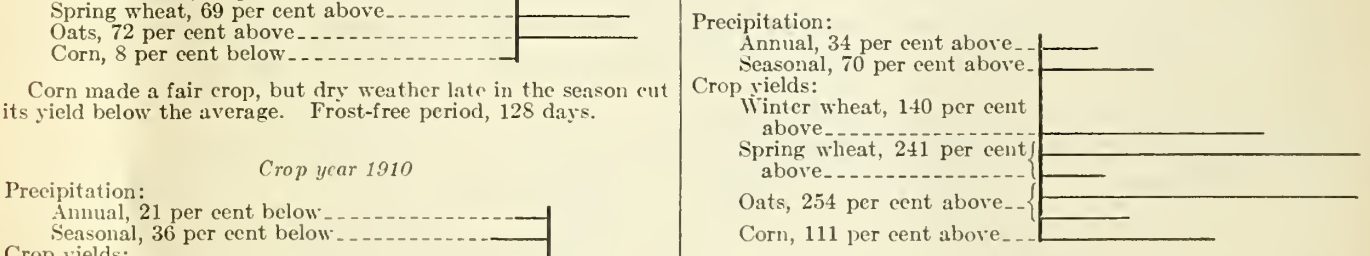
Small grains began to run short of water about the middle of June and showed injury thereafter. The rain on June 28 came when the spring grains were heading and saved them from total failure. Winter wheat was about two weeks farther advanced and made a good yield. Corn set only a few ears and dried up in the last half of August. Frost-free period, 142 days.

Crop year 1914



Small grains began to suffer about June 20 and finally dried up rather than ripened about the middle of July. Winter wheat was farther advanced and consequently suffered less than spring grains. Corn was ruined by the continued drought, conditions for it becoming critical about July 20. Frost-free period, 144 days.

Crop year 1915



The season was the most favorable for crop production that has been experienced in western South Dakota since that section has been settled. Corn did not all mature fully. Frost-free period, 119 days.

Crop year 1916

Small grains suffered from a lack of sufficient water in July but made about average yields. The relatively poor yield of winter wheat was due to winterkilling and to rust. Corn did not suffer from drought until shortly before harvest. Frost-free period, 120 days.

Crop year 1917

Precipitation:
- Annual, 13 per cent below
- Seasonal, 13 per cent below

Crop yields:
- Winter wheat, 75 per cent below
- Spring wheat, 56 per cent below
- Oats, 52 per cent below
- Corn, 3 per cent below

The season was unfavorable to small grains but fairly favorable to corn and other cultivated crops. The early spring was so wet and cold that small grains could not be planted until about three weeks later than usual. From the first week in June until harvest the rainfall was not sufficient for their needs. They began to suffer at about the heading stage in the latter part of June and continued to suffer from drought and exceptionally hot weather in July until they were harvested. Winter wheat suffered in addition from winterkilling, which reduced its stand and lowered its vitality until it was two weeks later than spring wheat. Corn was not far enough advanced for the hot dry weather of July to injure it seriously. August rains cared for its needs until it was far enough advanced to mature a fair crop. Frost-free period, 128 days.

Crop year 1918

Precipitation:
- Annual, 9 per cent below
- Seasonal, 5 per cent below

Crop yields:
- Winter wheat, 79 per cent above
- Spring wheat, 30 per cent below
- Oats, 34 per cent below
- Corn, 42 per cent above

There was a marked deficiency of rainfall in June, and spring-sown small grains suffered severely except on fallow. After the drought was broken early in July the rainfall was sufficient for the needs of the crops. Winter wheat did not come up until spring and was so much later than the spring grains at the time of the June drought that it was not so badly injured and was able to make a better recovery when the July rains came. Corn was not materially injured by the drought and developed normally. Frost-free period, 119 days.

Crop year 1919

Precipitation:
- Annual, 5 per cent below
- Seasonal, 31 per cent below

Crop yields:
- Winter wheat, 87 per cent below
- Spring wheat, 95 per cent below
- Oats, 97 per cent below
- Corn, 98 per cent below

Crops were almost complete failures. This was the result of exceptionally hot, windy weather in May and June combined with a drought lasting from the middle of April to the latter part of July. Frost-free period, 147 days.

Crop year 1920

Precipitation:
- Annual, 78 per cent above
- Seasonal, 114 per cent above

Crop yields:
- Winter wheat, 89 per cent below
- Spring wheat, 77 per cent above
- Oats, 80 per cent above
- Corn, 77 per cent above

The crop season was one of the most favorable experienced in western South Dakota. Winter wheat was practically destroyed by stem rust. The spring-sown small grains would have yielded still higher than they did if there had been more rain in the latter part of July or the first of August. Frost-free period, 148 days.

Crop year 1921

Precipitation:
- Annual, 16 per cent below
- Seasonal, 14 per cent below

Crop yields:
- Winter wheat, 64 per cent below
- Spring wheat, 57 per cent below
- Oats, 67 per cent below
- Corn, 57 per cent below

Land cropped in 1920 contained no stored water, and crops on it suffered from a lack of water at intervals throughout the season. Land fallowed in 1920 was well filled with water, and crops on it developed normally and grew to maturity without suffering severely for water for any considerable periods of time. Winter wheat on fallow was winterkilled or destroyed by soil blowing. Frost-free period, 137 days.

Crop year 1922

Precipitation:
- Annual, 30 per cent above
- Seasonal, 82 per cent above

Crop yields:
- Winter wheat, 104 per cent above
- Spring wheat, 91 per cent above
- Oats, 86 per cent above
- Corn, 100 per cent above

Continued rains during May, June, and July enabled small grains to mature without experiencing a shortage of water. The growth of corn was checked late in August by the exhaustion of available water, but it was far enough advanced to make a good yield of good quality. Frost-free period, 171 days.

Crop year 1923

Precipitation:
- Annual, 8 per cent above
- Seasonal, 27 per cent above

Crop yields:
- Winter wheat, 41 per cent above
- Spring wheat, 66 per cent above
- Oats, 62 per cent above
- Corn, 148 per cent above

The yields of small grains as a whole were lower than in 1922, but the yields of all cultivated crops were the highest on record at the station. All crops grew to maturity without suffering seriously for water at any stage of growth. There was some damage by grasshoppers and plant diseases; particularly rust on oats, rust and scab on wheat, and smut on corn were abundant and reduced yields somewhat. Frost-free period, 150 days.

Crop year 1924

Precipitation:
- Annual, 31 per cent above
- Seasonal, 56 per cent below

Crop yields:
- Winter wheat, 102 per cent above
- Spring wheat, 27 per cent above
- Oats, 24 per cent above
- Corn, 16 per cent below

The soil was filled with water from the heavy rains of the preceding fall. Low temperature and high humidity enabled crops to utilize this water so economically that they produced yields above the average in spite of a seasonal precipitation 56 per cent below the normal. At no time during the growth of small grains was the soil wet by rain to a depth greater than 2 inches. Cultivated crops were helped materially by a rain of 1.41 inches on August 5. Frost-free period, 132 days.

RESULTS AT ARDMORE, S. DAK.

[Altitude, 3,549 feet; 12-year period (figs. 20 and 21)]

Climatic conditions: Mean annual precipitation, 16.69 inches; mean seasonal precipitation, 10.84 inches; mean seasonal evaporation, 36.919 inches.

Average frost-free period, 136 days.

Soil: Gumbo, decomposed Pierre shale.

Number of crop yields averaged each year: Winter wheat, 12; spring wheat, 39; oats, 41; corn, 42.

Average annual crop yields per acre: Winter wheat, 14.9 bushels; spring wheat, 17.4 bushels; oats, 32.8 bushels; corn, 15 bushels.

Crop year 1913

Precipitation:
- Annual, 33 per cent below
- Seasonal, 36 per cent below

Crop yields:
- Winter wheat, 91 per cent below
- Spring wheat, 88 per cent below
- Oats, 93 per cent below
- Corn, 100 per cent below

Conditions were fairly favorable until the middle of June, when crops began to suffer from a lack of water. The rainfall

ARDMORE (S. DAK.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1912	4	.83	1.68	.55	.27	T	.03	.40	.50	1.52	2.04	1.59	1.78	11.19	W.WHEAT	1.4	1913
	3														S.WHEAT	2.0	
	2														OATS	2.3	
	1														CORN	0.0	
1913	4	1.23	1.50	1.59	.15	.90	.02	.45	.28	3.27	1.24	3.24	.49	14.36	W.WHEAT	0.0	1914
	3														S.WHEAT	0.0	
	2														OATS	0.0	
	1														CORN	0.0	
1914	4	1.79	.75	1.51	T	.43	.50	.64	.86	4.26	3.40	6.67	6.01	26.82	W.WHEAT	33.2	1915
	3														S.WHEAT	46.8	
	2														OATS	77.2	
	1														CORN	38.8	
1915	4	1.37	4.70	.81	.11	1.08	.25	.35	.54	1.04	3.61	2.58	1.80	18.24	W.WHEAT	31.3	1916
	3														S.WHEAT	21.1	
	2														OATS	39.8	
	1														CORN	22.1	
1916	4	1.90	.02	.85	.39	.20	.47	.09	1.02	2.74	5.34	1.71	.47	15.20	W.WHEAT	7.2	1917
	3														S.WHEAT	9.2	
	2														OATS	15.2	
	1														CORN	13.9	
1917	4	1.99	.43	.67	.18	.70	.48	.29	.60	2.85	5.99	1.75	3.49	19.42	W.WHEAT	19.4	1918
	3														S.WHEAT	35.0	
	2														OATS	65.1	
	1														CORN	22.2	
1918	4	.44	3.01	.45	.25	.66	T	.76	.93	2.52	2.65	1.50	3.05	16.22	W.WHEAT	18.3	1919
	3														S.WHEAT	11.6	
	2														OATS	22.4	
	1														CORN	9.2	
1919	4	.47	.38	2.10	.78	.14	.15	.73	.92	3.78	5.20	3.10	.77	18.52	W.WHEAT	25.7	1920
	3														S.WHEAT	28.1	
	2														OATS	56.8	
	1														CORN	19.3	
1920	4	1.59	.29	1.48	.29	.31	1.15	.18	.07	.52	2.41	4.54	1.26	14.09	W.WHEAT	16.0	1921
	3														S.WHEAT	19.6	
	2														OATS	42.5	
	1														CORN	7.9	
1921	4	.55	.46	.66	.68	.30	.55	.14	T	3.23	2.56	2.59	4.07	15.79	W.WHEAT	0.0	* 1922
	3														S.WHEAT	0.0	
	2														OATS	0.0	
	1														CORN	14.8	
1922	4	.78	.15	.83	2.19	.41	.05	.30	.40	.98	3.80	5.93	.67	16.49	W.WHEAT	17.4	1923
	3														S.WHEAT	24.4	
	2														OATS	59.1	
	1														CORN	29.5	
1923	4	3.09	1.52	1.48	.13	.25	.02	.75	.70	.69	.75	1.95	2.61	13.94	W.WHEAT	9.3	1924
	3														S.WHEAT	11.9	
	2														OATS	13.3	
	1														CORN	2.4	
AVERAGE		1.33	1.24	1.08	.45	.45	.31	.42	.57	2.28	3.25	3.10	2.21	16.69			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	* Hail destroyed all small grain in 1922		

FIG. 20.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Ardmore (S. Dak.) Field Station

after June 1 came in small showers, and the total quantity was inadequate to the needs of the crops, which practically failed entirely except on fallow. Frost-free period, 141 days.

Crop year 1914

Precipitation:
- Annual, 16 per cent below
- Seasonal, 24 per cent below

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 100 per cent below
- Oats, 100 per cent below
- Corn, 100 per cent below

Small grains promised good yields until they were destroyed by hail on June 24. Corn was injured by this and later hailstorms and finally suffered from drought before it was cut for fodder without producing any grain. Frost-free period, 125 days.

Crop year 1915

Precipitation:
- Annual, 61 per cent above
- Seasonal, 88 per cent above

Crop yields:
- Winter wheat, 123 per cent above
- Spring wheat, 169 per cent above
- Oats, 135 per cent above
- Corn, 159 per cent above

There was much lodging and some rust on the small grains. Frost-free period, 136 days.

Crop year 1916

Precipitation:
- Annual, 9 per cent above
- Seasonal, 17 per cent below

Crop yields:
- Winter wheat, 110 per cent above
- Spring wheat, 21 per cent above
- Oats, 21 per cent above
- Corn, 47 per cent above

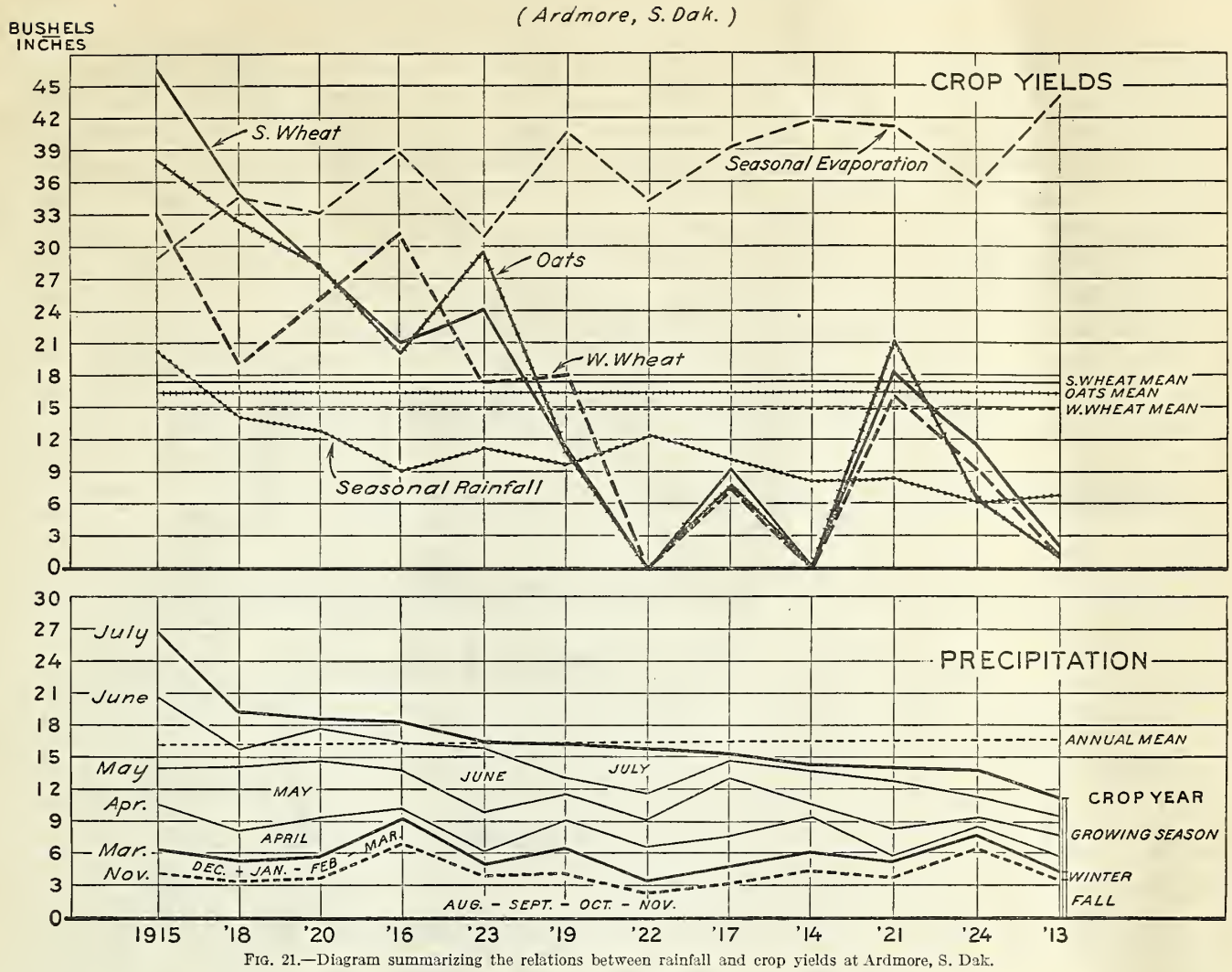


FIG. 21.—Diagram summarizing the relations between rainfall and crop yields at Ardmore, S. Dak.

The soil was well filled with water in the spring from the heavy precipitation of the preceding fall. Small grains experienced no lack of water until about the middle of July. After this time there was some shortage, but conditions were not severe or long continued. Winter wheat and barley yielded relatively much more than spring wheat and oats, because they were earlier. Corn went through the season under favorable conditions except that its maturity was hastened by hot, dry, windy weather. Frost-free period, 121 days.

Crop year 1917

Precipitation:
- Annual, 9 per cent below
- Seasonal, 5 per cent below

Crop yields:
- Winter wheat, 52 per cent below
- Spring wheat, 47 per cent below
- Oats, 54 per cent below
- Corn, 7 per cent below

Much of the precipitation in May and August was lost by run-off. Crops suffered from a cold late spring, drought, excessively high temperatures in late July and early August, and two hailstorms. Frost-free period, 150 days.

Crop year 1918

Precipitation:
- Annual, 16 per cent above
- Seasonal, 30 per cent above

Crop yields:
- Winter wheat, 30 per cent above
- Spring wheat, 101 per cent above
- Oats, 98 per cent above
- Corn, 48 per cent above

This was next to the wettest year in the history of the station and a year of heavy production. Frost-free period, 129 days.

Crop year 1919

Precipitation:
- Annual, 3 per cent below
- Seasonal, 10 per cent below

Crop yields:
- Winter wheat, 23 per cent above
- Spring wheat, 33 per cent below
- Oats, 32 per cent below
- Corn, 39 per cent below

Small grains suffered for water at intervals in both May and June and before harvest in July. Winter wheat profited by its earliness and yielded above the average. Corn suffered from drought in the latter part of the season. Frost-free period, 130 days.

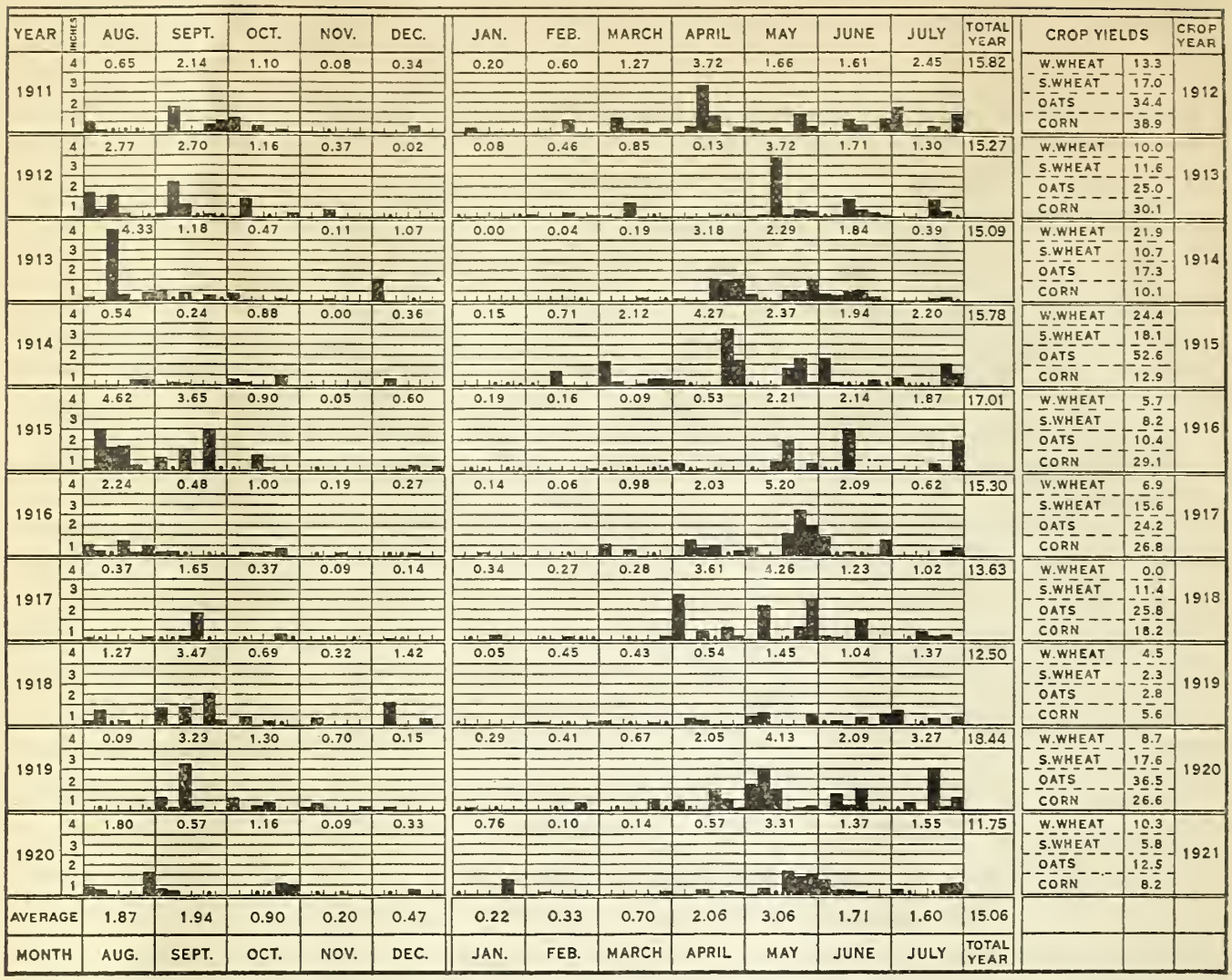
Crop year 1920

Precipitation:
- Annual, 11 per cent above
- Seasonal, 19 per cent above

Crop yields:
- Winter wheat, 73 per cent above
- Spring wheat, 62 per cent above
- Oats, 73 per cent above
- Corn, 29 per cent above

The rainfall after June 20 was deficient, but the soil was well filled with water, and there was little suffering from a lack of it. Frost-free period, 149 days.

SCOTTSBLUFF (NEBR.) FIELD STATION



YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1911	4	0.65	2.14	1.10	0.08	0.34	0.20	0.60	1.27	3.72	1.66	1.61	2.45	15.82	W.WHEAT	13.3	1912
	3														S.WHEAT	17.0	
	2														OATS	34.4	
	1														CORN	38.9	
1912	4	2.77	2.70	1.16	0.37	0.02	0.08	0.46	0.85	0.13	3.72	1.71	1.30	15.27	W.WHEAT	10.0	1913
	3														S.WHEAT	11.6	
	2														OATS	25.0	
	1														CORN	30.1	
1913	4	4.33	1.18	0.47	0.11	1.07	0.00	0.04	0.19	3.18	2.29	1.84	0.39	15.09	W.WHEAT	21.9	1914
	3														S.WHEAT	10.7	
	2														OATS	17.3	
	1														CORN	10.1	
1914	4	0.54	0.24	0.88	0.00	0.36	0.15	0.71	2.12	4.27	2.37	1.94	2.20	15.78	W.WHEAT	24.4	1915
	3														S.WHEAT	18.1	
	2														OATS	52.6	
	1														CORN	12.9	
1915	4	4.62	3.65	0.90	0.05	0.60	0.19	0.16	0.09	0.53	2.21	2.14	1.87	17.01	W.WHEAT	5.7	1916
	3														S.WHEAT	8.2	
	2														OATS	10.4	
	1														CORN	29.1	
1916	4	2.24	0.48	1.00	0.19	0.27	0.14	0.06	0.98	2.03	5.20	2.09	0.62	15.30	W.WHEAT	6.9	1917
	3														S.WHEAT	15.6	
	2														OATS	24.2	
	1														CORN	26.8	
1917	4	0.37	1.65	0.37	0.09	0.14	0.34	0.27	0.28	3.61	4.26	1.23	1.02	13.63	W.WHEAT	0.0	1918
	3														S.WHEAT	11.4	
	2														OATS	25.8	
	1														CORN	18.2	
1918	4	1.27	3.47	0.69	0.32	1.42	0.05	0.45	0.43	0.54	1.45	1.04	1.37	12.50	W.WHEAT	4.5	1919
	3														S.WHEAT	2.3	
	2														OATS	2.8	
	1														CORN	5.6	
1919	4	0.09	3.29	1.30	0.70	0.15	0.29	0.41	0.67	2.05	4.13	2.09	3.27	18.44	W.WHEAT	8.7	1920
	3														S.WHEAT	17.6	
	2														OATS	36.5	
	1														CORN	26.6	
1920	4	1.80	0.57	1.16	0.09	0.33	0.76	0.10	0.14	0.57	3.31	1.37	1.55	11.75	W.WHEAT	10.3	1921
	3														S.WHEAT	5.8	
	2														OATS	12.5	
	1														CORN	8.2	
AVERAGE		1.87	1.94	0.90	0.20	0.47	0.22	0.33	0.70	2.06	3.06	1.71	1.60	15.06			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 22.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Scottsbluff (Nebr.) Field Station

Crop year 1921

Precipitation:
- Annual, 16 per cent below
- Seasonal, 19 per cent below

Crop yields:
- Winter wheat, 7 per cent above
- Spring wheat, 7 per cent above
- Oats, 30 per cent above
- Corn, 47 per cent below

The precipitation was particularly deficient in April and from about June 20 to the end of the growing season. Corn began suffering from drought about July 10, and the condition was not relieved. Small grains suffered from a lack of water during the latter part of their growing season. Frost-free period, 137 days.

Crop year 1922

Precipitation:
- Annual, 5 per cent below
- Seasonal, 15 per cent above

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 100 per cent below
- Oats, 100 per cent below
- Corn, 1 per cent below

Exceptionally promising crops of small grains were completely destroyed by hail on July 1. Corn was about 3 feet high and was badly damaged, but there was plenty of water available, and recovery was much more rapid and complete than appeared possible. The yield would have been much higher if the crop had not been damaged by the hail. Frost-free period, 135 days.

Crop year 1923

Precipitation:
- Annual, 1 per cent below
- Seasonal, 5 per cent above

Crop yields:
- Winter wheat, 17 per cent above
- Spring wheat, 40 per cent above
- Oats, 80 per cent above
- Corn, 97 per cent above

July was very dry. Small grains suffered for water during that month. Conditions were favorable for corn throughout the season and the second highest yield in the history of the station was obtained. Frost-free period, 157 days.

Crop year 1924

Precipitation:
- Annual, 16 per cent below
- Seasonal, 45 per cent below

Crop yields:
- Winter wheat, 38 per cent below
- Spring wheat, 32 per cent below
- Oats, 59 per cent below
- Corn, 84 per cent below

Soil moisture conditions were very unsatisfactory in the spring. The rainfall was not sufficient for the needs of the small grains, and by the last of June they were beyond the possibility of recovery to make a good crop. Corn was beyond recovery by the end of July. It continued to suffer and finally dried up with practically no grain on it in any of the fields. The yields of small grains were remarkably good, considering the character of the season. Frost-free period, 128 days.

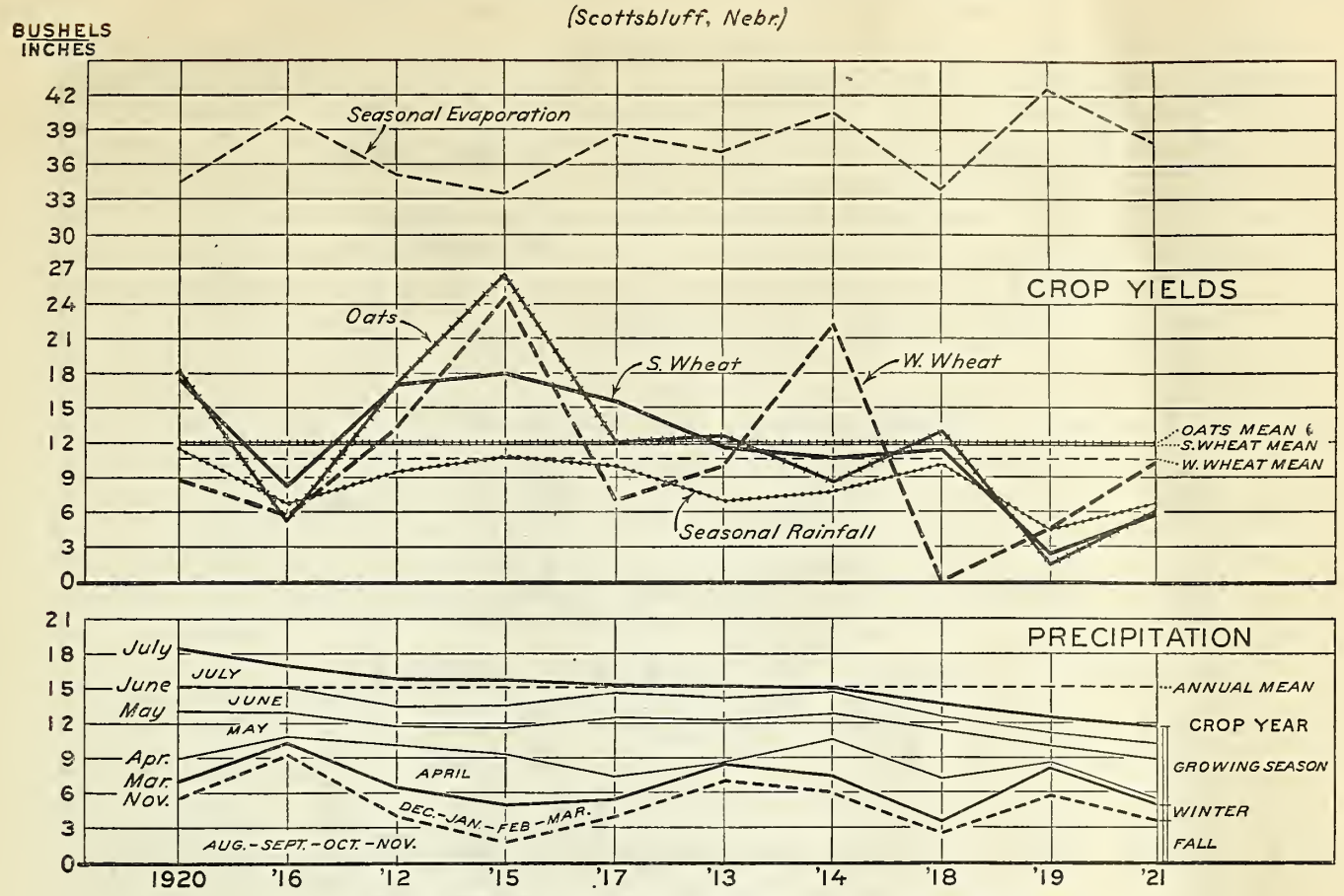


FIG. 23.—Diagram summarizing the relations between rainfall and crop yields at Scottsbluff, Nebr.

RESULTS AT SCOTTSBLUFF, NEBR.

[Altitude, 3,900 feet; 10-year period (figs. 22 and 23)]

Climatic conditions: Mean annual precipitation, 15.06 inches; mean seasonal precipitation, 8.43 inches; mean seasonal evaporation, 37.391 inches.

Average frost-free period, 130 days.

Soil: Brule clay, above the ditch level on irrigated farm.

Number of crop yields averaged each year: Winter wheat, 11; spring wheat, 27; oats, 37; corn, 36.

Average annual crop yields per acre: Winter wheat, 10.6 bushels; spring wheat, 11.8 bushels; oats, 24.1 bushels; corn, 20.7 bushels.

Crop year 1912

Precipitation:
- Annual, 5 per cent above
- Seasonal, 11 per cent above

Crop yields:
- Winter wheat, 27 per cent above
- Spring wheat, 45 per cent above
- Oats, 43 per cent above
- Corn, 88 per cent above

Winter precipitation was good, and the soil was in fine condition at seeding time. There was some winterkilling of winter wheat. Frost-free period, 125 days.

Crop year 1913

Precipitation:
- Annual, 1 per cent above
- Seasonal, 19 per cent below

Crop yields:
- Winter wheat, 6 per cent below
- Spring wheat, 2 per cent below
- Oats, 4 per cent above
- Corn, 46 per cent above

Crops began to suffer from drought about June 20, and the rain that fell thereafter until the small grains were harvested was inadequate to their needs. Later rains enabled corn to make a good yield. Winter wheat suffered from winterkilling as well as from drought. Frost-free period, 140 days.

Crop year 1914

Precipitation:
- Annual, mean.
- Seasonal, 9 per cent below

Crop yields:
- Winter wheat, 107 per cent above
- Spring wheat, 9 per cent below
- Oats, 28 per cent below
- Corn, 51 per cent below

Conditions for crop growth were favorable until June 22. There was little precipitation to benefit crops after that date, and the spring grains and corn ripened prematurely or dried up. Spring grains were heading about the time conditions became unfavorable, but winter wheat was farther advanced and produced a good crop. Frost-free period, 129 days.

Crop year 1915

Precipitation:
- Annual, 5 per cent above
- Seasonal, 27 per cent above

Crop yields:
- Winter wheat, 130 per cent above
- Spring wheat, 53 per cent above
- Oats, 118 per cent above
- Corn, 38 per cent below

The stand of winter wheat was poor, as a result of the dry fall and winter. Precipitation during the growing season was abundant. A hail storm on August 7 reduced the average yield of spring wheat, which was only partly harvested, and destroyed the prospects for a fair yield of corn. Other grains were harvested before the hail and were but little injured by it. Frost-free period, 113 days.

NORTH PLATTE (NEBR.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1906	4	5.56	4.25	3.05	1.01	0.96	0.39	0.51	0.10	0.23	2.61	2.53	4.74	25.94	BARLEY	37.7	1907
	3														S.WHEAT	24.7	
	2														OATS	31.4	
	1														CORN	20.2	
1907	4	1.80	2.44	0.64	0.31	0.80	0.16	0.78	0.20	0.45	4.59	6.01	3.44	21.62	BARLEY	35.5	1908
	3														S.WHEAT	26.6	
	2														OATS	61.1	
	1														CORN	26.1	
1908	4	1.88	0.20	3.41	0.59	0.20	0.29	1.61	0.98	0.55	3.09	4.99	5.48	23.27	BARLEY	19.1	1909
	3														S.WHEAT	17.2	
	2														OATS	28.4	
	1														CORN	26.4	
1909	4	1.73	0.46	0.22	2.24	1.37	0.34	0.02	0.19	0.62	1.76	3.11	0.12	12.18	BARLEY	15.2	1910
	3														S.WHEAT	8.2	
	2														OATS	13.1	
	1														CORN	5.3	
1910	4	3.21	0.97	0.01	0.11	0.72	0.28	0.39	0.20	2.34	1.34	0.50	3.61	13.68	BARLEY	0.0	1911
	3														S.WHEAT	0.0	
	2														OATS	0.0	
	1														CORN	0.6	
1911	4	2.64	1.26	3.45	0.04	0.65	0.74	0.81	3.08	3.02	1.72	0.70	2.78	20.89	W.WHEAT	9.7	1912
	3														S.WHEAT	6.4	
	2														OATS	13.7	
	1														CORN	27.2	
1912	4	1.33	2.04	1.44	0.01	0.18	0.16	0.94	1.68	2.09	2.44	2.81	2.76	17.88	W.WHEAT	14.4	1913
	3														S.WHEAT	3.3	
	2														OATS	0.0	
	1														CORN	0.0	
1913	4	1.28	0.99	0.14	0.14	3.09	0.18	0.96	0.41	1.46	1.66	4.59	1.37	16.27	W.WHEAT	7.3	1914
	3														S.WHEAT	5.9	
	2														OATS	9.8	
	1														CORN	5.3	
1914	4	3.54	0.16	1.39	T.	0.87	0.51	1.11	2.23	6.77	5.80	4.76	6.19	33.33	W.WHEAT	35.5	1915
	3														S.WHEAT	27.2	
	2														OATS	69.3	
	1														CORN	28.2	
1915	4	3.19	2.09	1.16	0.22	0.82	0.85	0.81	0.20	0.70	2.23	4.40	0.40	17.07	W.WHEAT	30.9	1916
	3														S.WHEAT	18.2	
	2														OATS	37.4	
	1														CORN	7.2	
1916	4	2.88	1.40	0.50	0.47	0.42	0.74	0.35	1.48	1.45	4.02	2.00	0.78	16.49	W.WHEAT	0.0	1917
	3														S.WHEAT	6.7	
	2														OATS	8.5	
	1														CORN	7.3	
1917	4	3.46	2.45	0.39	0.71	0.27	0.54	0.28	0.32	2.32	3.26	1.82	1.93	17.75	W.WHEAT	7.9	1918
	3														S.WHEAT	5.2	
	2														OATS	9.1	
	1														CORN	21.2	
1918	4	1.98	0.46	1.43	0.29	1.31	0.03	1.50	0.44	1.77	2.72	7.33	5.33	24.59	W.WHEAT	21.8	1919
	3														S.WHEAT	15.1	
	2														OATS	38.4	
	1														CORN	34.1	
1919	4	1.12	1.81	1.36	2.83	0.32	0.07	0.72	0.38	4.24	3.49	1.93	3.31	21.58	W.WHEAT	28.3	1920
	3														S.WHEAT	17.3	
	2														OATS	42.8	
	1														CORN	33.9	
1920	4	4.52	0.15	1.29	0.04	0.60	0.68	0.36	0.42	1.17	2.43	1.14	3.12	15.92	W.WHEAT	23.6	1921
	3														S.WHEAT	9.7	
	2														OATS	18.1	
	1														CORN	15.5	
1921	4	3.50	1.56	0.92	0.04	0.14	0.66	0.05	0.47	2.88	6.17	6.17	4.69	20.27	W.WHEAT	13.0	1922
	3														S.WHEAT	4.3	
	2														OATS	14.0	
	1														CORN	28.4	
1922	4	2.35	0.66	0.14	2.35	0.01	0.11	0.14	0.38	2.02	6.17	4.63	5.52	24.48	W.WHEAT	15.1	1923
	3														S.WHEAT	19.6	
	2														OATS	60.6	
	1														CORN	47.3	
1923	4	3.80	1.40	1.77	0.45	0.39	0.36	0.36	1.93	0.36	2.48	2.35	1.81	17.18	W.WHEAT	37.3	1924
	3														S.WHEAT	16.4	
	2														OATS	54.5	
	1														CORN	22.8	
AVERAGE		2.77	1.37	1.26	0.66	0.73	0.38	0.65	0.84	1.91	3.11	3.15	3.19	20.02			
MONTH		AUG.	SEPT	OCT.	NOV.	DEC.	JAN	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 24.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the North Platte (Nebr.) Field Station

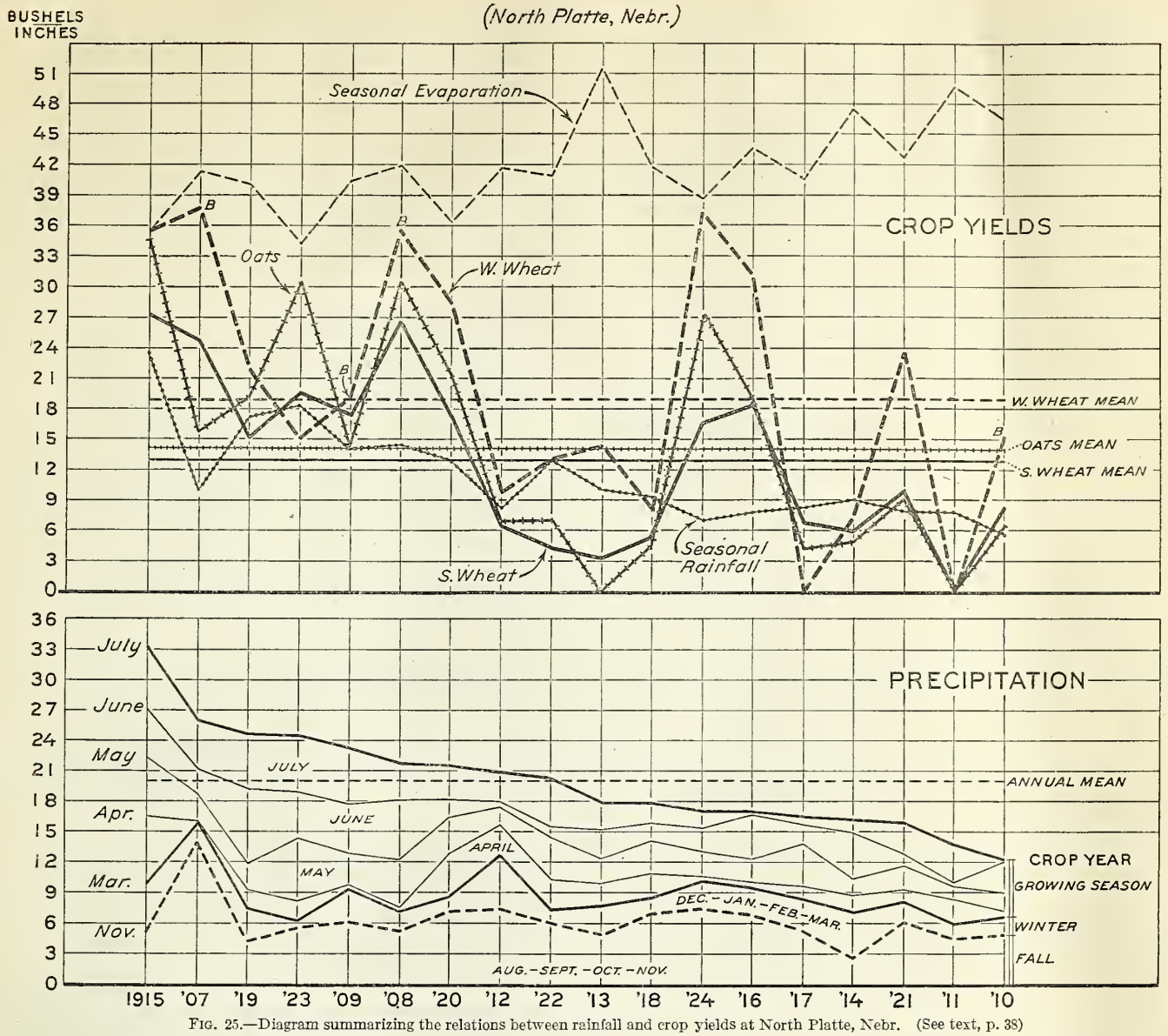


FIG. 25.—Diagram summarizing the relations between rainfall and crop yields at North Platte, Nebr. (See text, p. 38)

Crop year 1916

Precipitation:
- Annual, 13 per cent above
- Seasonal, 20 per cent below

Crop yields:
- Winter wheat, 46 per cent below
- Spring wheat, 30 per cent below
- Oats, 57 per cent below
- Corn, 41 per cent above

The heavy precipitation in the fall of 1915 made the precipitation for the crop year above the average. Conditions were unfavorable to all crops except corn. There was some winterkilling in winter wheat, and all small grains suffered from drought, high winds, and soil blowing in the spring. There were three damaging hailstorms on June 1, 2, and 12. The last was particularly severe and practically destroyed the small grains. Frost-free period, 122 days.

Crop year 1917

Precipitation:
- Annual, 2 per cent above
- Seasonal, 18 per cent above

Crop yields:
- Winter wheat, 35 per cent below
- Spring wheat, 32 per cent above
- Oats, mean.
- Corn, 30 per cent above

Two-thirds of the winter wheat was destroyed by winterkilling and soil blowing. The spring was very wet, but the summer after June 5 was exceptionally dry, and all small grains suffered seriously from drought. Spring wheat withstood the conditions better than the other small grains. Corn suffered some from grasshoppers as well as drought. Frost-free period, 150 days.

Crop year 1918

Precipitation:
- Annual, 9 per cent below
- Seasonal, 20 per cent above

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 3 per cent below
- Oats, 7 per cent above
- Corn, 12 per cent below

The season was comparatively unfavorable to crop production. Due to unfavorable conditions in the fall, no stand of winter wheat was secured. About the middle of July small grains began to show the effects of drought. A few days of hot wind came at this critical time and ripened the grain prematurely. Corn suffered from the drought in July and August. All crops were damaged some by grasshoppers. Frost-free period, 128 days.

Crop year 1919

Precipitation:
- Annual, 17 per cent below
- Seasonal, 48 per cent below

Crop yields:
- Winter wheat, 58 per cent below
- Spring wheat, 81 per cent below
- Oats, 88 per cent below
- Corn, 73 per cent below

The season was the most disastrous to crops in the history of the station. The precipitation was scant, and there were periods of extreme heat and hot winds. Frost-free period, 111 days.

Crop year 1920

Precipitation:
- Annual, 22 per cent above
- Seasonal, 37 per cent above

Crop yields:
- Winter wheat, 18 per cent below
- Spring wheat, 49 per cent above
- Oats, 51 per cent above
- Corn, 29 per cent above

Winter wheat suffered from soil blowing in March. Frost-free period, 142 days.

Crop year 1921

Precipitation:
- Annual, 22 per cent below
- Seasonal, 19 per cent below

Crop yields:
- Winter wheat, 3 per cent below
- Spring wheat, 51 per cent below
- Oats, 48 per cent below
- Corn, 60 per cent below

The chief source of damage was dry weather in June and July. Frost-free period, 140 days.

RESULTS AT NORTH PLATTE, NEBR.

[Altitude, 2,821 feet; 18-year period (figs. 24 and 25)]

Climatic conditions: Mean annual precipitation, 20.02 inches; mean seasonal precipitation, 11.36 inches; mean seasonal evaporation, 41.955 inches.

Average frost-free period, 154 days.

Soil: Loess on high plateau 100 feet above valley of Platte River; very deep and uniform.

Number of crop yields averaged each year: Winter wheat, 25; spring wheat, 19; oats, 23; barley, 5; corn, 22.

Average annual crop yields per acre: Barley, 21.5 bushels; winter wheat, 18.8 bushels; spring wheat, 12.9 bushels; oats, 28.3 bushels; corn, 19.8 bushels.

Crop year 1907

Precipitation:
- Annual, 30 per cent above
- Seasonal, 11 per cent below

Crop yields:
- Barley, 75 per cent above
- Spring wheat, 91 per cent above
- Oats, 11 per cent above
- Corn, 2 per cent above

The spring opened early but was cold and dry. The drought continued until May 20, and the last freeze was May 26. The stand and vitality of spring-sown small grains suffered, oats being affected more than wheat. Oats also suffered material loss from smut. Corn was not planted until after the spring drought, but it suffered more or less from the drought beginning the last of July and continuing through August. Frost-free period, 139 days.

Crop year 1908

Precipitation:
- Annual, 8 per cent above
- Seasonal, 28 per cent above

Crop yields:
- Barley, 65 per cent above
- Spring wheat, 106 per cent above
- Oats, 116 per cent above
- Corn, 32 per cent above

The dry spring retarded the growth of straw, and later rains encouraged the filling of the grain. Corn suffered quite severely from late drought. Frost-free period, 151 days.

Crop year 1909

Precipitation:
- Annual, 16 per cent above
- Seasonal, 24 per cent above

Crop yields:
- Barley, 11 per cent below
- Spring wheat, 33 per cent above
- Oats, mean.
- Corn, 33 per cent above

Crops did not suffer materially from a lack of water during the season, but stands were seriously reduced by late spring freezes and high winds. Wheat was injured less than barley and oats. Frost-free period, 164 days.

Crop year 1910

Precipitation:
- Annual, 39 per cent below
- Seasonal, 51 per cent below

Crop yields:
- Barley, 30 per cent below
- Spring wheat, 36 per cent below
- Oats, 54 per cent below
- Corn, 73 per cent below

The stand and vitality of small grains suffered from freezes in the last half of April, but the primary cause of the low yields in 1910 was drought. Both the crop year and the season were the driest in the history of the station. Frost-free period, 156 days.

Crop year 1911

Precipitation:
- Annual, 32 per cent below
- Seasonal, 31 per cent below

Crop yields:
- Barley, 100 per cent below
- Spring wheat, 100 per cent below
- Oats, 100 per cent below
- Corn, 97 per cent below

This was the second driest year in the history of the station. Probably some grain would have been produced on fallow if it had not been destroyed by grasshoppers. Frost-free period, 155 days.

Crop year 1912

Precipitation:
- Annual, 4 per cent above
- Seasonal, 28 per cent below

Crop yields:
- Winter wheat, 49 per cent below
- Spring wheat, 50 per cent below
- Oats, 52 per cent below
- Corn, 37 per cent above

Small grains began to show drought damage about the 25th of May and suffered serious damage from hot winds the last three days of that month. The light rains from June 5 to 13 only slightly relieved the situation, but they saved the crops from total failure. The rains of July and the first half of August made the corn crop. Frost-free period, 157 days.

Crop year 1913

Precipitation:
- Annual, 11 per cent below
- Seasonal, 11 per cent below

Crop yields:
- Winter wheat, 23 per cent below
- Spring wheat, 74 per cent below
- Oats, 100 per cent below
- Corn, 100 per cent below

The first seeding of oats failed to make a stand on account of spring freezes, and it was necessary to reseed, which made the oats late. They were badly fired by the middle of June and were eaten up by grasshoppers by July 9. Spring wheat made a good growth of straw but did not fill, on account of hot winds and the lack of water. Winter wheat had a heavy growth of straw by the fore part of June, but hot weather and a lack of water resulted in a very poor fill. Grasshoppers began eating the corn in the latter part of June and continued until all prospects of a crop were gone before the middle of August. They were assisted in the destruction by a hailstorm on July 15. Frost-free period, 154 days.

Crop year 1914

Precipitation:
- Annual, 19 per cent below
- Seasonal, 20 per cent below

Crop yields:
- Winter wheat, 61 per cent below
- Spring wheat, 54 per cent below
- Oats, 65 per cent below
- Corn, 73 per cent below

Small grains made a fair to good growth of straw, but the lack of rain after June 21 and grasshopper injury resulted in very poor yields of grain. Corn was suffering badly from drought and grasshoppers by July 10. Grasshoppers continued to work throughout the month until the leaves were gone. Rains in the latter part of August were too late to be of much help. Frost-free period, 149 days.

Crop year 1915

Precipitation:
- Annual, 66 per cent above
- Seasonal, 107 per cent above

Crop yields:
- Winter wheat, 89 per cent above
- Spring wheat, 111 per cent above
- Oats, 145 per cent above
- Corn, 42 per cent above

This was the wettest year since records began in 1875, with the greater part of the excess occurring during the growing season. Yields were very heavy. Winter wheat suffered some loss by lodging, with rust and scab in the lodged spots. Corn suffered some damage by grasshoppers and a hailstorm and was not fully mature when frosted. Frost-free period, 138 days.

Crop year 1916

Precipitation:
- Annual, 15 per cent below
- Seasonal, 32 per cent below

Crop yields:
- Winter wheat, 64 per cent above
- Spring wheat, 41 per cent above
- Oats, 32 per cent above
- Corn, 62 per cent below

The soil was filled with water from the heavy rains of the previous year. Small grains suffered some from hot, dry weather in the later stages of growth. Winter wheat was so far advanced when dry weather set in that it was little damaged. By the time the drought ended on August 11 much of the corn was beyond recovery. Frost-free period, 169 days.

Crop year 1917

Precipitation:
- Annual, 18 per cent below
- Seasonal, 27 per cent below

Crop yields:
- Winter wheat, 100 per cent below
- Spring wheat, 48 per cent below
- Oats, 70 per cent below
- Corn, 63 per cent below

The limiting factor in crop production was water. No rain of any consequence fell from June 5 until after the small grains were harvested. Corn revived somewhat after the rains beginning August 19, but much of it was beyond recovery. Winter wheat failed to survive the winter. Frost-free period, 157 days.

Crop year 1918

Precipitation:
- Annual, 11 per cent below
- Seasonal, 18 per cent below

Crop yields:
- Winter wheat, 58 per cent below
- Spring wheat, 60 per cent below
- Oats, 68 per cent below
- Corn, 7 per cent above

June was the severe month of the growing season. High temperatures and a deficient water supply combined to bring about a critical condition. Small grains came into head, but filling of the grain was very imperfect, ripening was premature, and yields were very low. Corn was not seriously injured at this time. Later rains were sufficient for its needs. Frost-free period, 133 days.

Crop year 1919

Precipitation:
- Annual, 23 per cent above
- Seasonal, 51 per cent above

Crop yields:
- Winter wheat, 16 per cent above
- Spring wheat, 17 per cent above
- Oats, 36 per cent above
- Corn, 72 per cent above

Small grains, particularly oats and winter wheat, suffered considerable loss from rust. Frost-free period, 161 days.

Crop year 1920

Precipitation:
- Annual, 8 per cent above
- Seasonal, 14 per cent above

Crop yields:
- Winter wheat, 51 per cent above
- Spring wheat, 34 per cent above
- Oats, 51 per cent above
- Corn, 69 per cent above

The quantity and the distribution of the precipitation was such that crops did not suffer acutely for lack of water at any time. Frost-free period, 152 days.

Crop year 1921

Precipitation:
- Annual, 20 per cent below
- Seasonal, 31 per cent below

Crop yields:
- Winter wheat, 26 per cent above
- Spring wheat, 25 per cent below
- Oats, 36 per cent below
- Corn, 22 per cent below

Early prospects for small grains were good, but a shortage of water in June caused rapid deterioration and premature ripening. Winter wheat, being farther advanced, suffered less than other crops. The yield of corn was reduced by dry weather, but the quality was unusually good. Frost-free period, 155 days.

Crop year 1922

Precipitation:
- Annual, 1 per cent above
- Seasonal, 14 per cent above

Crop yields:
- Winter wheat, 31 per cent below
- Spring wheat, 67 per cent below
- Oats, 50 per cent below
- Corn, 43 per cent above

Small grains presented an unusually fine appearance the first week in June, but continued dry weather during that month resulted in a rapid decline, an early harvest, and very low yields. The distribution of the precipitation was quite favorable for corn. The yield of that crop was above the average, and its quality was good. Frost-free period, 172 days.

Crop year 1923

Precipitation:
- Annual, 22 per cent above
- Seasonal, 62 per cent above

Crop yields:
- Winter wheat, 20 per cent below
- Spring wheat, 52 per cent above
- Oats, 114 per cent above
- Corn, 139 per cent above

The crop had an abundance of water. The average yield of winter wheat was low, owing to the fact that winter survival was poor except on fallow. Frost-free period, 157 days.

Crop year 1924

Precipitation:
- Annual, 14 per cent below
- Seasonal, 38 per cent below

Crop yields:
- Winter wheat, 98 per cent above
- Spring wheat, 27 per cent above
- Oats, 93 per cent above
- Corn, 15 per cent above

The season was characterized by deficiencies in precipitation, temperature, and evaporation. The soil was well filled with water; the distribution of the rainfall was very favorable, especially to small grains, while low temperatures during the drier periods did much to prevent serious drought injury. Frost-free period, 161 days.

ARCHER (WYO.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1913	4	2.09	2.23	0.66	0.46	1.65	T.	0.60	0.56	2.54	1.46	1.12	1.43	14.80	S. WHEAT	7.0	1914
	3														W. WHEAT	5.6	
	2														OATS	16.5	
	1														CORN	14.0	
1914	4	2.03	0.32	1.29	0.26	0.16	0.08	0.49	0.71	4.90	1.78	1.83	1.65	15.50	S. WHEAT	24.8	1915
	3														W. WHEAT	26.0	
	2														OATS	39.6	
	1														CORN	0.0	
1915	4	2.53	1.95	1.81	0.03	0.56	0.10	0.09	0.19	0.74	1.61	0.48	1.81	11.90	S. WHEAT	4.0	1916
	3														W. WHEAT	5.2	
	2														OATS	6.5	
	1														CORN	19.9	
1916	4	4.05	1.37	0.73	0.88	0.34	0.06	0.80	0.85	1.87	4.54	0.46	1.79	17.74	S. WHEAT	14.8	1917
	3														W. WHEAT	14.0	
	2														OATS	28.8	
	1														CORN	21.1	
1917	4	1.20	0.91	0.57	0.40	0.81	0.47	0.89	0.19	4.14	1.86	2.78	2.74	16.96	S. WHEAT	23.3	1918
	3														W. WHEAT	14.5	
	2														OATS	32.8	
	1														CORN	30.2	
1918	4	1.66	2.41	1.33	0.54	0.58	T.	0.14	0.87	0.58	0.31	0.59	2.76	11.77	S. WHEAT	3.8	1919
	3														W. WHEAT	1.4	
	2														OATS	1.3	
	1														CORN	6.0	
1919	4	1.19	3.10	1.48	1.26	1.10	0.20	0.69	0.34	3.88	2.08	4.33	1.21	20.86	S. WHEAT	3.5	1920
	3														W. WHEAT	4.6	
	2														OATS	13.6	
	1														CORN	4.8	
1920	4	1.25	0.88	0.57	0.15	0.27	0.95	0.07	0.14	0.86	2.19	2.47	1.79	11.59	S. WHEAT	10.0	1921
	3														W. WHEAT	18.1	
	2														OATS	12.4	
	1														CORN	12.2	
1921	4	0.76	0.08	0.21	0.08	0.73	0.32	0.28	0.20	2.33	2.15	2.30	1.81	11.25	S. WHEAT	3.7	1922
	3														W. WHEAT	2.4	
	2														OATS	1.7	
	1														CORN	15.1	
1922	4	2.36	0.14	0.06	2.23	0.44	0.06	0.42	1.06	0.86	2.98	2.69	1.38	14.68	S. WHEAT	13.6	1923
	3														W. WHEAT	10.2	
	2														OATS	16.2	
	1														CORN	35.6	
1923	4	4.59	1.14	3.32	0.16	0.09	0.06	0.30	0.87	0.58	3.38	0.86	0.50	15.85	S. WHEAT	10.5	1924
	3														W. WHEAT	17.0	
	2														OATS	17.3	
	1														CORN	16.1	
AVERAGE		2.16	1.32	1.09	0.59	0.61	0.21	0.43	0.54	2.12	2.21	1.81	1.72	14.81			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 26.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Archer (Wyo.) Field Station

RESULTS AT ARCHER, WYO.

[Altitude, 1,481 feet; 11-year period (figs. 26 and 27)]

Climatic conditions: Mean annual precipitation, 14.81 inches; mean seasonal precipitation, 7.86 inches; mean seasonal evaporation, 36.897 inches.

Average frost-free period, 138 days.

Soil: Clay loam "hard land."

Number of crop yields averaged each year: Spring wheat, 30; winter wheat, 13; oats, 34; corn, 37.

Average annual crop yields per acre: Spring wheat, 10.8 bushels; winter wheat, 10.8 bushels; oats, 17 bushels; corn, 15.9 bushels.

Crop year 1914

Precipitation:
- Annual, mean.
- Seasonal, 17 per cent below

Crop yields:
- Spring wheat, 35 per cent below
- Winter wheat, 48 per cent below
- Oats, 3 per cent below
- Corn, 12 per cent below

All crops were damaged by hail on June 14. Small grains suffered from drought which followed the hailstorm and was not broken until July 26. Corn yields were reduced by drought in August. Frost-free period, 130 days.

Crop year 1915

Precipitation:
- Annual, 5 per cent above
- Seasonal, 29 per cent above

Crop yields:
- Spring wheat, 130 per cent above
- Winter wheat, 141 per cent above
- Oats, 133 per cent above
- Corn, 100 per cent below

The cool season and an ample supply of water at all times favored the growth of small grains. Yields were probably reduced a little by rust. The season was too cool for corn, which had only reached the roasting-ear stage when frosted on October 3. Frost-free period, 114 days.

Crop year 1916

Precipitation:
- Annual, 20 per cent below
- Seasonal, 41 per cent below

Crop yields:
- Spring wheat, 63 per cent below
- Winter wheat, 52 per cent below
- Oats, 69 per cent below
- Corn, 25 per cent above

Drought was the cause of the low yields of small grains. All plats reached the heading stage, but many did not fill. Winter

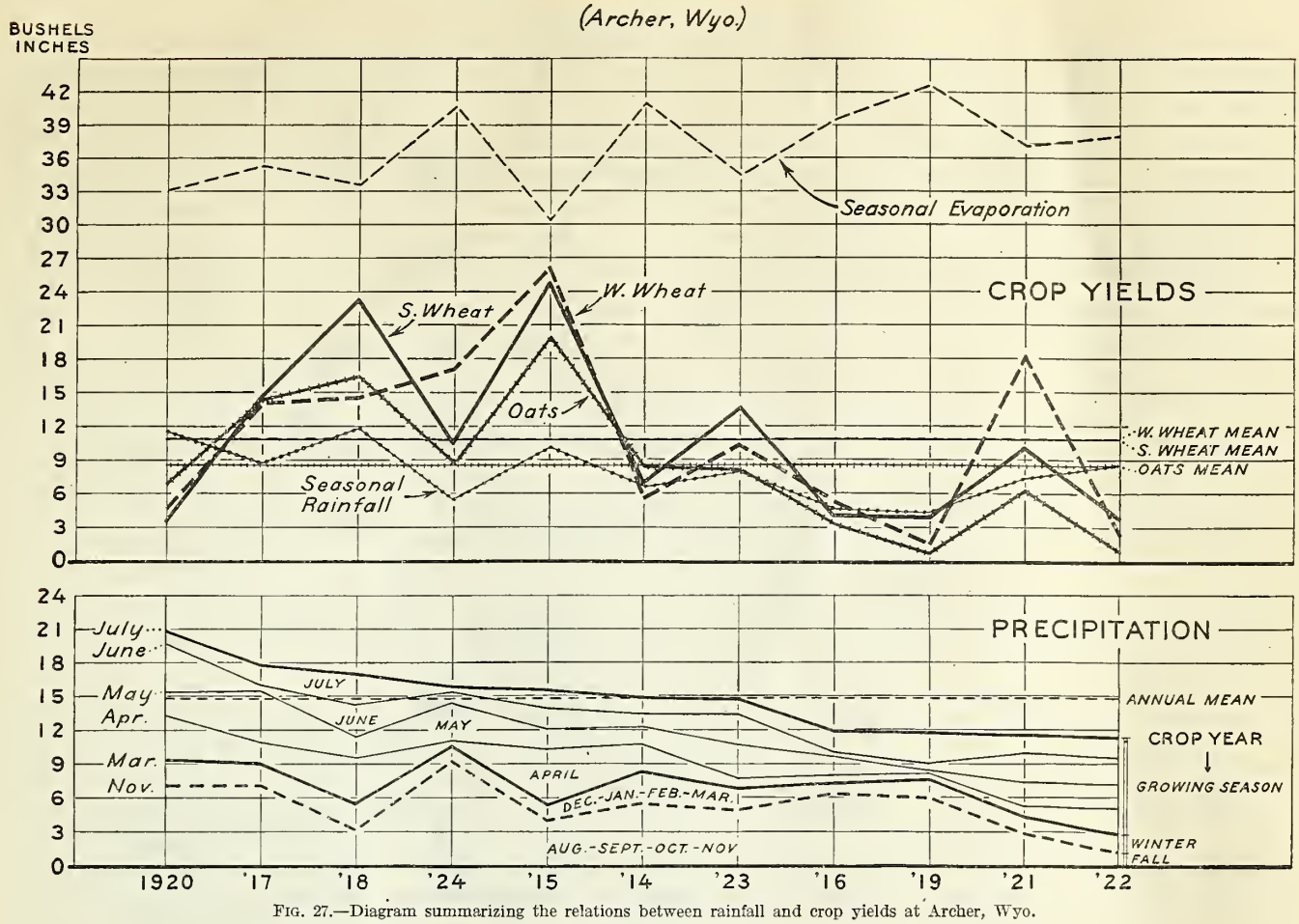


FIG. 27.—Diagram summarizing the relations between rainfall and crop yields at Archer, Wyo.

wheat suffered from soil blowing in the latter part of March. The rainfall of late July and the month of August enabled corn to make a crop 25 per cent above the average. Frost-free period, 134 days.

Crop year 1917

Precipitation:
- Annual, 20 per cent above
- Seasonal, 10 per cent above

Crop yields:
- Spring wheat, 37 per cent above
- Winter wheat, 30 per cent above
- Oats, 69 per cent above
- Corn, 33 per cent above

Winter wheat was injured by soil blowing and on plats under most methods was killed when the temperature went down to 4° F. on April 30. It was reseeded to spring wheat. The season was unusually late, and all crops made a slow growth until the latter part of June. The water supply was sufficient for their needs. Frost-free period, 154 days.

Crop year 1918

Precipitation:
- Annual, 15 per cent above
- Seasonal, 47 per cent above

Crop yields:
- Spring wheat, 116 per cent above
- Winter wheat, 34 per cent above
- Oats, 93 per cent above
- Corn, 90 per cent above

The water supply was sufficient for the needs of the crops at all times, and yields were among the highest recorded at the station. Frost-free period, 167 days.

Crop year 1919

Precipitation:
- Annual, 21 per cent below
- Seasonal, 46 per cent below

Crop yields:
- Spring wheat, 65 per cent below
- Winter wheat, 92 per cent below
- Oats, 92 per cent below
- Corn, 62 per cent below

The small precipitation before July 1 made conditions very unfavorable to crops. In addition to the drought damage, winter wheat winterkilled on most of the plats and was reseeded to spring wheat. Spring wheat was injured by rust. Oats and corn especially were damaged by hail on August 7. Corn was very soft. Frost-free period, 123 days.

Crop year 1920

Precipitation:
- Annual, 41 per cent above
- Seasonal, 46 per cent above

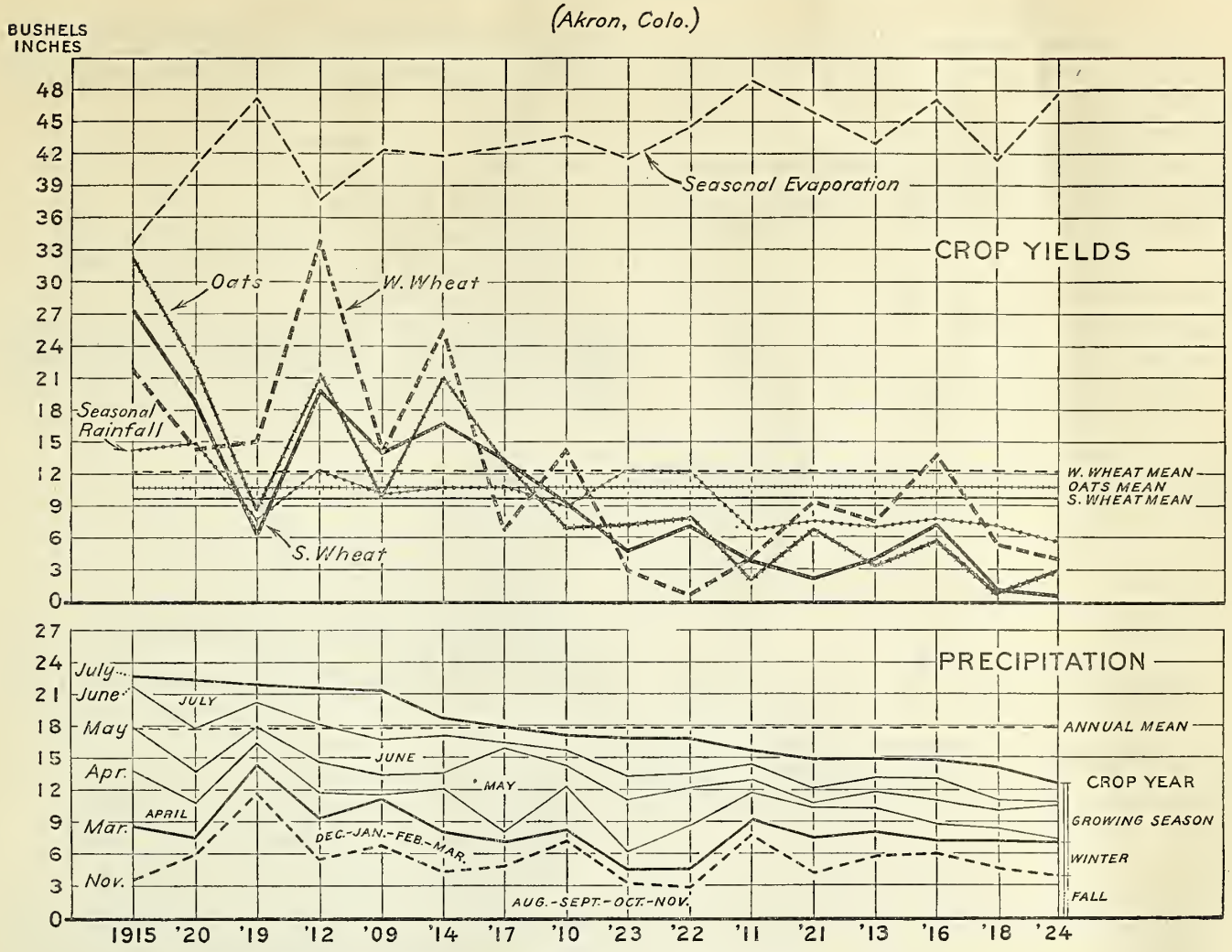
Crop yields:
- Spring wheat, 68 per cent below
- Winter wheat, 57 per cent below
- Oats, 20 per cent below
- Corn, 70 per cent below

The spring was very cold and wet, and the growth of crops was further delayed by heavy hail storms in June. Seeding was delayed pending administrative action as to the continuation of the work. Frost-free period, 137 days.

AKRON (COLO.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1908	4	1.47	0.05	3.20	2.00	T.	T.	1.38	3.06	0.40	1.87	3.32	4.61	21.36	W.WHEAT	14.1	1909
	3														S.WHEAT	13.8	
	2														OATS	19.4	
	1														CORN	24.9	
1909	4	3.77	2.12	0.86	0.48	0.55	0.05	0.16	0.26	3.96	2.06	1.38	1.47	17.12	W.WHEAT	14.1	1910
	3														S.WHEAT	9.2	
	2														OATS	13.3	
	1														CORN	10.9	
1910	4	3.72	3.81	0.05	0.12	0.32	0.60	0.44	0.06	2.63	1.15	1.48	1.34	15.72	W.WHEAT	4.1	1911
	3														S.WHEAT	3.7	
	2														OATS	4.0	
	1														CORN	3.2	
1911	4	1.30	2.40	1.47	0.28	1.36	0.28	1.43	0.78	2.49	2.86	3.39	3.58	21.62	W.WHEAT	33.8	1912
	3														S.WHEAT	19.7	
	2														OATS	42.3	
	1														CORN	30.9	
1912	4	1.58	1.88	1.99	0.18	0.29	0.22	0.40	1.57	2.19	1.44	1.35	1.85	14.94	W.WHEAT	7.4	1913
	3														S.WHEAT	3.9	
	2														OATS	6.6	
	1														CORN	3.9	
1913	4	1.14	2.08	0.34	0.70	3.27	0.03	0.32	0.20	4.01	1.46	3.54	1.66	18.75	W.WHEAT	25.5	1914
	3														S.WHEAT	16.6	
	2														OATS	42.2	
	1														CORN	11.3	
1914	4	1.05	0.23	2.08	0.10	0.90	1.10	1.68	1.50	5.19	4.13	3.75	1.10	22.81	W.WHEAT	21.8	1915
	3														S.WHEAT	27.3	
	2														OATS	64.3	
	1														CORN	29.2	
1915	4	3.51	1.76	0.48	0.15	0.65	0.50	T.	0.09	1.59	2.24	2.09	1.77	14.83	W.WHEAT	13.7	1916
	3														S.WHEAT	7.1	
	2														OATS	11.3	
	1														CORN	1.1	
1916	4	2.82	0.26	1.02	0.75	0.61	0.28	0.63	0.72	0.96	7.79	0.56	1.52	17.92	W.WHEAT	6.6	1917
	3														S.WHEAT	13.2	
	2														OATS	26.2	
	1														CORN	15.2	
1917	4	1.78	2.19	0.57	T.	0.50	0.70	0.80	0.60	1.20	1.76	0.96	3.10	14.16	W.WHEAT	5.3	1918
	3														S.WHEAT	1.1	
	2														OATS	1.4	
	1														CORN	12.4	
1918	4	7.36	2.43	1.07	0.75	1.55	0.07	0.50	0.65	1.96	1.59	2.27	1.79	21.99	W.WHEAT	15.0	1919
	3														S.WHEAT	6.3	
	2														OATS	16.9	
	1														CORN	4.5	
1919	4	0.44	2.62	1.64	1.29	0.70	0.00	0.02	0.90	3.28	2.90	3.97	4.72	22.48	W.WHEAT	14.2	1920
	3														S.WHEAT	18.7	
	2														OATS	44.2	
	1														CORN	35.6	
1920	4	1.45	1.80	0.44	0.47	0.90	1.22	T.	1.25	2.77	0.47	1.32	2.88	14.97	W.WHEAT	12.3	1921
	3														S.WHEAT	2.1	
	2														OATS	13.1	
	1														CORN	6.3	
1921	4	0.92	0.79	0.97	0.20	0.65	0.65	0.25	0.15	3.96	3.63	1.43	3.24	16.84	W.WHEAT	0.6	1922
	3														S.WHEAT	6.9	
	2														OATS	15.9	
	1														CORN	11.2	
1922	4	1.24	0.06	0.05	1.90	0.10	T.	0.18	0.95	1.65	4.94	2.17	3.62	16.86	W.WHEAT	2.9	1923
	3														S.WHEAT	4.6	
	2														OATS	14.4	
	1														CORN	17.9	
1923	4	0.75	0.82	1.91	0.47	0.70	0.50	0.59	1.25	0.31	3.26	0.35	1.71	12.62	W.WHEAT	3.9	1924
	3														S.WHEAT	0.5	
	2														OATS	5.8	
	1														CORN	1.8	
AVERAGE		2.14	1.58	1.13	0.62	0.82	0.39	0.55	0.87	2.41	2.72	2.08	2.50	17.81			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 28.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Akron (Colo.) Field Station



(FIG. 29.—Diagram summarizing the relations between rainfall and crop yields at Akron, Colo. (See text, p. 44)

Crop year 1921

Precipitation:
- Annual, 22 per cent below
- Seasonal, 7 per cent below

Crop yields:
- Spring wheat, 7 per cent below
- Winter wheat, 68 per cent above
- Oats, 27 per cent below
- Corn, 23 per cent below

Small grains began to suffer from drought about July 10. Winter wheat suffered less than spring wheat, because it was farther advanced. Corn was affected later by the drought. Frost-free period, 139 days.

Crop year 1922

Precipitation:
- Annual, 24 per cent below
- Seasonal, 9 per cent above

Crop yields:
- Spring wheat, 66 per cent below
- Winter wheat, 78 per cent below
- Oats, 90 per cent below
- Corn, 5 per cent below

The fall and winter of 1921–22 were unusually dry, the precipitation for the eight months from August to March, inclusive, being less than 3 inches. There being no reserve water in the soil, crops were extremely sensitive to droughty conditions under a seasonal precipitation only 9 per cent above the normal. There was no stand of winter wheat in the spring, and plats were reseeded to spring wheat. Corn survived the drought much better than the small grains. Frost-free period, 128 days.

Crop year 1923

Precipitation:
- Annual, 1 per cent below
- Seasonal, 1 per cent above

Crop yields:
- Spring wheat, 26 per cent above
- Winter wheat, 6 per cent below
- Oats, 5 per cent below
- Corn, 124 per cent above

Much of the winter wheat was killed by soil blowing in the winter. Spring seeding was late. The yields of wheat and oats were reduced by rust, and oats were damaged by hail as they were ripening. Conditions were very favorable to corn, the late rains causing a heavy production of grain. Frost-free period, 149 days.

Crop year 1924

Precipitation:
- Annual, 7 per cent above
- Seasonal, 32 per cent below

Crop yields:
- Spring wheat, 3 per cent below
- Winter wheat, 57 per cent above
- Oats, 2 per cent above
- Corn, 1 per cent above

The season of 1924 was marked by a severe drought during June, July, and August. The relatively good yield of winter wheat was due to the heavy precipitation in the fall of 1923 and in May, 1924. Corn and spring-sown small grains were able to make about average yields. Frost-free period, 146 days.

RESULTS AT AKRON, COLO.

[Altitude, 4,669 feet; 16-year period (figs. 28 and 29)]

Climatic conditions: Mean annual precipitation, 17.81 inches; mean seasonal precipitation, 9.71 inches; mean seasonal evaporation, 43.116 inches.

Average frost-free period, 139 days.

Soil: Clay loam, "hard land."

Number of crop yields averaged each year: Winter wheat, 17; spring wheat, 23; oats, 31; corn, 27.

Average annual crop yields per acre: Winter wheat, 12.2 bushels; spring wheat, 9.7 bushels; oats, 21.3 bushels; corn, 13.8 bushels.

Crop year 1909

Precipitation:
- Annual, 20 per cent above
- Seasonal, 5 per cent above

Crop yields:
- Winter wheat, 16 per cent above
- Spring wheat, 42 per cent above
- Oats, 9 per cent below
- Corn, 80 per cent above

No stand was obtained with winter wheat, and it was reseeded to spring wheat. The season was generally favorable. Some damage was done by hailstorms on June 9 and July 7. Frost-free period, 140 days.

Crop year 1910

Precipitation:
- Annual, 8 per cent below
- Seasonal, 9 per cent below

Crop yields:
- Winter wheat, 16 per cent above
- Spring wheat, 5 per cent below
- Oats, 38 per cent below
- Corn, 21 per cent below

Crops suffered from the drought that extended from June 5 to July 29. Small grains began to suffer about June 12 and corn about July 4. Later rains enabled the corn that set to mature, but small grains were all harvested by July 18. Frost-free period, 132 days.

Crop year 1911

Precipitation:
- Annual, 12 per cent below
- Seasonal, 32 per cent below

Crop yields:
- Winter wheat, 66 per cent below
- Spring wheat, 62 per cent below
- Oats, 81 per cent below
- Corn, 12 per cent below

Small grains made a slow growth in April and May, and during June they suffered acutely from drought. Corn made a good growth in June, but was severely injured by drought in July. Frost-free period, 150 days.

Crop year 1912

Precipitation:
- Annual, 22 per cent above
- Seasonal, 27 per cent above

Crop yields:
- Winter wheat, 117 per cent above.
- Spring wheat, 103 per cent above.
- Oats, 99 per cent above
- Corn, 124 per cent above

Small grains suffered very little from drought or damage from any cause. Corn fired some in September and was not fully mature when frosted on September 20. Frost-free period, 130 days.

Crop year 1913

Precipitation:
- Annual, 16 per cent below
- Seasonal, 30 per cent below

Crop yields:
- Winter wheat, 39 per cent below
- Spring wheat, 60 per cent below
- Oats, 69 per cent below
- Corn, 72 per cent below

The spring was very cold and late, with a sudden change in temperature and the beginning of a prolonged drought about the middle of May. Winter wheat began to suffer from drought in May, and all small grains were firing badly by the middle of June. Corn began to suffer the first week in July. Frost-free period, 139 days.

Crop year 1914

Precipitation:
- Annual, 5 per cent above
- Seasonal, 10 per cent above

Crop yields:
- Winter wheat, 109 per cent above
- Spring wheat, 71 per cent above
- Oats, 98 per cent above
- Corn, 18 per cent below

All small grains made good yields, although they suffered from drought for nearly two weeks before they were harvested about the middle of July. Corn suffered more seriously from the drought at this time and again in the latter part of August. Frost-free period, 124 days.

Crop year 1915

Precipitation:
- Annual, 28 per cent above
- Seasonal, 46 per cent above

Crop yields:
- Winter wheat, 79 per cent above
- Spring wheat, 181 per cent above
- Oats, 202 per cent above
- Corn, 112 per cent above

Winter wheat suffered some loss by winterkilling. Small-grain harvest was about three weeks later than usual. The maturity of corn was also late. Frost-free period, 137 days.

Crop year 1916

Precipitation:
- Annual, 17 per cent below
- Seasonal, 21 per cent below

Crop yields:
- Winter wheat, 12 per cent above
- Spring wheat, 27 per cent below
- Oats, 47 per cent below
- Corn, 93 per cent below

Precipitation was deficient but was supplemented to some extent by water stored in the soil from the excess of the previous season. Winter wheat made short straw but filled well and was the only crop to yield above the average. Spring-sown small grains on plats under most methods did not grow tall enough to harvest with a binder. Corn began to suffer from drought early in July and on many methods did not tassel. Frost-free period, 121 days.

Crop year 1917

Precipitation:
- Annual, 1 per cent above
- Seasonal, 12 per cent above

Crop yields:
- Winter wheat, 46 per cent below
- Spring wheat, 36 per cent above
- Oats, 23 per cent above
- Corn, 9 per cent above

The stand of winter wheat in 1917 was seriously reduced by drought, low temperatures, and soil blowing in March and April. Wheat and oats suffered from drought, and some plats did not fill well. Much of the corn was soft. Frost-free period, 149 days.

Crop year 1918

Precipitation:
- Annual, 20 per cent below
- Seasonal, 28 per cent below

Crop yields:
- Winter wheat, 57 per cent below
- Spring wheat, 89 per cent below
- Oats, 95 per cent below
- Corn, 10 per cent below

Small grains burned badly, winter wheat early in June and spring grains during the latter part of the month. Winter wheat ripened the first of July, and spring grains dried up about a week later. Straw was too short to bind except on fallow, and on many plats it was too short and thin to harvest at all.

Corn burned badly the first of July, but rains later in the month saved a part of it, and the heavy precipitation of August supplied water to mature a crop only 10 per cent below the average. Frost-free period, 165 days.

Crop year 1919

Precipitation:
- Annual, 23 per cent above
- Seasonal, 22 per cent below

Crop yields:
- Winter wheat, 23 per cent above
- Spring wheat, 35 per cent below
- Oats, 21 per cent below
- Corn, 67 per cent below

Small grains began to suffer from drought the middle of June. Straw was short, and some of the spring-sown grain did not head out. Winter wheat being farther advanced suffered less and was the only crop to yield above its average. Corn began to suffer from drought in July, and on many plats it did not tassel. Frost-free period, 122 days.

Crop year 1920

Precipitation:
- Annual, 26 per cent above
- Seasonal, 53 per cent above

Crop yields:
- Winter wheat, 16 per cent above
- Spring wheat, 93 per cent above
- Oats, 108 per cent above
- Corn, 158 per cent above

Ample rainfall nicely distributed made 1920 one of the best crop years in the agricultural history of the region. Frost-free period, 136 days.

Crop year 1921

Precipitation:
- Annual, 16 per cent below
- Seasonal, 23 per cent below

Crop yields:
- Winter wheat, 1 per cent above
- Spring wheat, 78 per cent below
- Oats, 38 per cent below
- Corn, 54 per cent below

Small grains began to suffer from drought early in June. Winter wheat being farther advanced than spring-sown small grains was able to mature a better crop. The yield of winter wheat on fallow was especially good. Corn began to suffer early in July, but the heavy rain of July 22 came in time to allow it to make a partial yield of grain. Frost-free period, 151 days.

Crop year 1922

Precipitation:
- Annual, 5 per cent below
- Seasonal, 26 per cent above

Crop yields:
- Winter wheat, 95 per cent below
- Spring wheat, 29 per cent below
- Oats, 25 per cent below
- Corn, 19 per cent below

Winter wheat did not survive the dry fall, winter, and spring. Small grains began to suffer about the middle of June from deficient precipitation. The continued dry weather with high temperatures in the first of July caused them to head short, ripen rapidly, and yield poorly. Conditions favored corn until the latter part of August, when a lack of water reduced its prospective yield. Frost-free period, 160 days.

Crop year 1923

Precipitation:
- Annual, 5 per cent below
- Seasonal, 28 per cent above

Crop yields:
- Winter wheat, 76 per cent below
- Spring wheat, 53 per cent below
- Oats, 42 per cent below
- Corn, 29 per cent above

Winter wheat did not germinate in the fall and in the spring made a poor stand of plants of low vitality. The yields of spring wheat and oats were cut down by wind, drought, and high temperatures in the latter part of June and the first of July. The light August rainfall seriously cut down the prospective yield of corn. Frost-free period, 136 days.

Crop year 1924

Precipitation:
- Annual, 29 per cent below
- Seasonal, 42 per cent below

Crop yields:
- Winter wheat, 68 per cent below
- Spring wheat, 95 per cent below
- Oats, 73 per cent below
- Corn, 87 per cent below

With the crop-year precipitation 29 per cent below and the seasonal precipitation 42 per cent below the normal, all crops nearly or quite failed. Frost-free period, 130 days.

RESULTS AT COLBY, KANS.

[Altitude, 3,138 feet; 11-year period (figs. 30 and 31)]

Climatic conditions: Mean annual precipitation, 20.29 inches; mean seasonal precipitation, 11.11 inches; mean seasonal evaporation, 39.819 inches.

Average frost-free period, 155 days.

Soil: Clay loam (Colby silt loam).

Number of crop yields averaged each year: Winter wheat, 41; barley, 6; milo, 35; corn, 15.

Average annual crop yields per acre: Winter wheat, 19.2 bushels; barley, 22.6 bushels; milo, 16.5 bushels; corn, 20.9 bushels.

Crop year 1914

Precipitation:
- Annual, 3 per cent above
- Seasonal, 5 per cent above

Crop yields:
- Winter wheat, 42 per cent below
- Barley (none sown).
- Milo (no yields).
- Corn, 96 per cent below

When the Colby station was established the experimental field had been seeded to winter wheat. This was allowed to remain on all small-grain plats. The wheat on the plats to be planted to corn and other cultivated crops was about 6 inches high when plowed or listed up. The crops that followed suffered from a lack of the water which the wheat had used and produced very little or no grain. The season was very favorable to winter wheat in the section, but the yields on the station plats were below the average for the locality. Frost-free period, 161 days.

Crop year 1915

Precipitation:
- Annual, 27 per cent above
- Seasonal, 69 per cent above

Crop yields:
- Winter wheat, 31 per cent above
- Barley, 115 per cent above
- Milo, 90 per cent below
- Corn, 137 per cent above

There was some lodging and poor filling of winter wheat, evidenced by a light weight per bushel. The season being wet and cool was unusually favorable to spring-sown small grains, but too cool for corn, and much of it was soft when frost came. May and June were so cold and wet that it was impossible to secure good stands of milo, and only the earliest heads were mature when frosted on October 5. Frost-free period, 137 days.

Crop year 1916

Precipitation:
- Annual, 19 per cent below
- Seasonal, 23 per cent below

Crop yields:
- Winter wheat, 15 per cent above
- Barley, 59 per cent below
- Milo, 100 per cent below
- Corn, 97 per cent below

The water stored in the soil from the rains of 1915 and the distribution of the precipitation during the early part of the season were favorable to the production of a good crop of winter wheat of high quality. Dry weather in early spring and a heavy

COLBY (KANS.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV.	DEC	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1913	4	0.62	2.69	0.29	0.56	4.36	0.05	0.45	0.21	1.21	3.07	2.32	5.01	20.84	W.WHEAT	11.2	1914
	3														BARLEY	---	
	2														MILO	---	
	1				T.										CORN	0.8	
1914	4	1.85	0.52	0.87	T.	0.51	0.38	1.49	1.43	3.61	4.55	4.03	6.60	25.84	W.WHEAT	25.1	1915
	3														BARLEY	48.5	
	2														MILO	1.7	
	1														CORN	49.6	
1915	4	4.17	0.67	1.10	0.48	0.48	0.55	0.05	0.33	2.03	1.33	3.15	2.07	16.41	W.WHEAT	22.0	1916
	3														BARLEY	9.2	
	2														MILO	0.0	
	1														CORN	0.6	
1916	4	1.48	0.40	0.62	0.21	0.37	0.12	0.20	0.56	1.66	1.99	1.42	3.07	12.10	W.WHEAT	0.0	1917
	3														BARLEY	0.0	
	2														MILO	2.5	
	1														CORN	1.2	
1917	4	5.78	4.25	0.28	0.42	0.20	0.77	1.79	1.34	1.05	2.18	0.19	1.86	20.09	W.WHEAT	17.0	1918
	3														BARLEY	5.8	
	2														MILO	6.1	
	1														CORN	1.1	
1918	4	1.88	2.16	2.87	0.21	2.63	T.	1.57	0.59	2.80	2.23	2.47	3.95	23.36	W.WHEAT	30.1	1919
	3														BARLEY	44.3	
	2														MILO	31.4	
	1														CORN	25.6	
1919	4	0.65	2.07	0.82	1.63	0.19	0.23	0.31	0.46	3.74	2.42	5.68	4.19	22.39	W.WHEAT	31.5	1920
	3														BARLEY	28.5	
	2														MILO	26.4	
	1														CORN	52.4	
1920	4	3.75	2.56	2.71	0.27	1.31	1.15	0.03	0.58	1.88	1.85	3.52	4.24	23.85	W.WHEAT	23.9	1921
	3														BARLEY	17.1	
	2														MILO	23.6	
	1														CORN	23.4	
1921	4	2.23	2.80	0.45	0.18	0.46	0.18	0.35	1.26	4.08	2.55	1.34	2.74	18.62	W.WHEAT	22.5	1922
	3														BARLEY	19.2	
	2														MILO	20.3	
	1														CORN	21.2	
1922	4	1.38	0.43	0.08	3.13	0.02	0.05	0.18	0.88	2.80	6.28	3.27	3.46	21.96	W.WHEAT	5.5	1923
	3														BARLEY	35.6	
	2														MILO	43.5	
	1														CORN	45.9	
1923	4	3.55	1.87	3.33	0.12	0.75	0.22	1.82	1.67	0.48	1.30	0.80	1.77	17.68	W.WHEAT	22.3	1924
	3														BARLEY	18.1	
	2														MILO	9.3	
	1														CORN	8.4	
AVERAGE		2.48	1.86	1.22	0.66	1.03	0.34	0.75	0.85	2.30	2.70	2.56	3.54	20.29			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 30.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Colby (Kans.) Field Station

weed growth made conditions unfavorable to spring-sown small grains. Dry hot weather in July and August prevented corn from earing. Poor stands of sorghums were obtained. Their growth was stunted by a dry hot summer, and a rather early frost prevented their maturity. Frost-free period, 135 days.

Crop year 1917

Precipitation:
- Annual, 40 per cent below
- Seasonal, 27 per cent below

Crop yields:
- Winter wheat, 100 per cent below
- Barley, 100 per cent below
- Milo, 85 per cent below
- Corn, 94 per cent below

Small grains were total failures. Little winter wheat survived the dry fall, winter, and spring. That which did was injured by hail on June 5. The failure of spring-sown small grains was due to a dry soil to start with, a lack of sufficient seasonal precipitation, and damage by hail and hot winds. Corn was seriously injured by drought in the latter part of June and during July. The August rainfall came too late. The crop was injured by hail on June 5 and again early in August. Grain sorghums were delayed in growth up to the first of August by hot dry weather and hot winds. They were set back by the hail in early August and were frosted when only a small part of the seed was mature. Frost-free period, 153 days.

Crop year 1918

Precipitation:
- Annual, 1 per cent below
- Seasonal, 53 per cent below

Crop yields:
- Winter wheat, 11 per cent below
- Barley, 74 per cent below
- Milo, 63 per cent below
- Corn, 95 per cent below

Winter wheat suffered severely from drought the latter part of May. A heavy rain on May 30 saved the crop, but it was again materially damaged by hot winds and dry weather during the latter part of June. Spring-sown small grains were first injured by a hard northwest wind on May 9 which caused some soil blowing and was followed by a freeze. They suffered like the winter wheat from drought and hot winds. Corn did well until it tasseled, but hot dry weather in August prevented it from earing well. Grasshoppers contributed to the injury. The first planting of milo was washed out or covered up by the dashing rain of May 30, and June plantings failed to come up on account of the hot dry weather. The limited stand that was obtained produced fairly well, although its yield was kept down by dry weather. Frost-free period, 169 days.

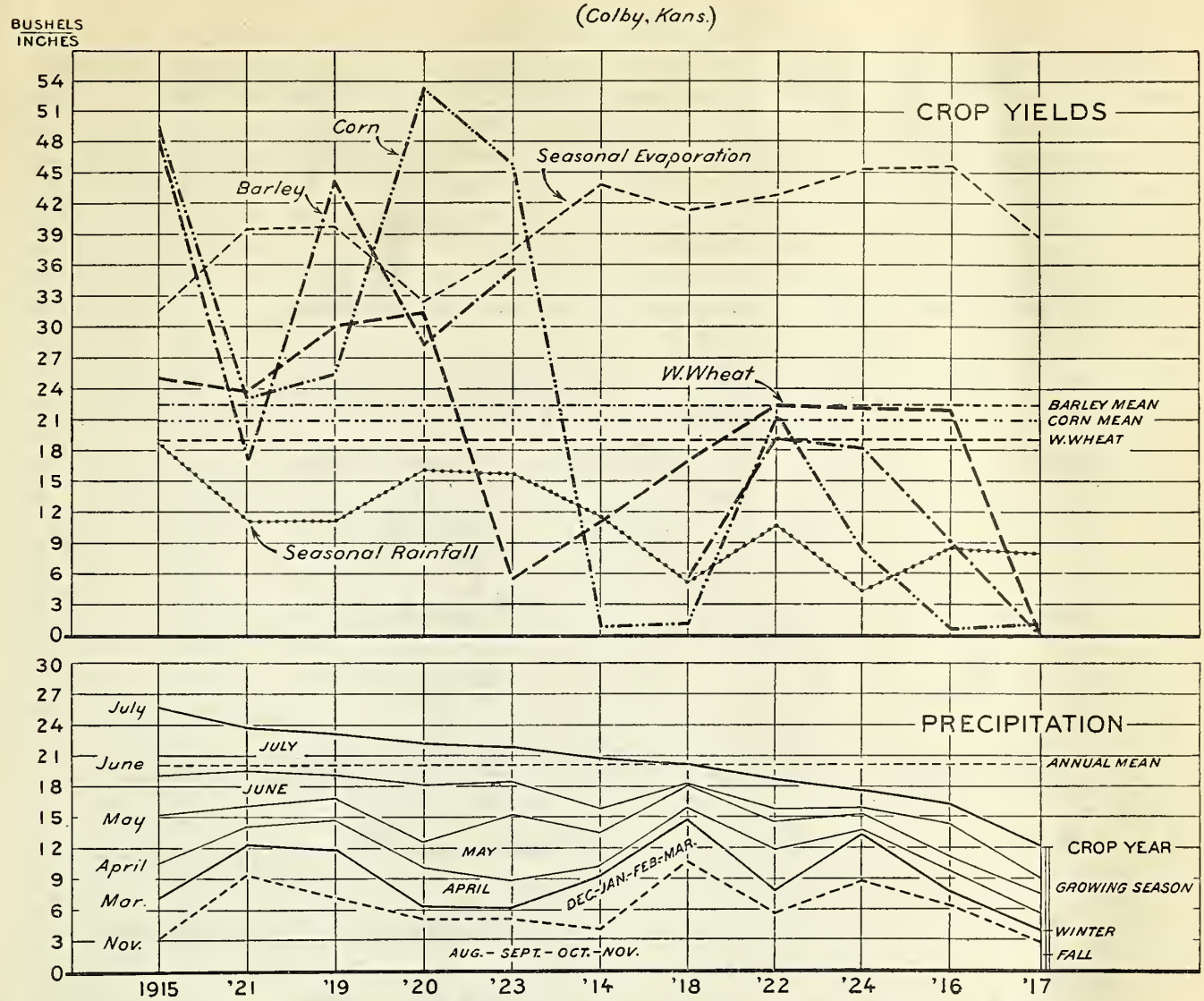


FIG. 31.—Diagram summarizing the relations between rainfall and crop yields at Colby, Kans. (See text, p. 45)

Crop year 1919

Precipitation:
- Annual, 15 per cent above
- Seasonal, 3 per cent above

Crop yields:
- Winter wheat, 57 per cent above
- Barley, 96 per cent above
- Milo, 90 per cent above
- Corn, 22 per cent above

Conditions were very critical for winter wheat in the latter part of May and for corn in the first part of July, but rains came in time to relieve the situation. Hot winds and dry weather in the latter part of June checked the filling of spring-sown small grains and reduced the prospective yields. Barley being farther advanced suffered less loss than spring wheat and oats. Winter wheat was too far advanced to be seriously affected. Corn suffered some from drought before the rains in August and was materially injured by hot wind in August. Conditions were decidedly favorable for milo. Frost-free period, 168 days.

Crop year 1920

Precipitation:
- Annual, 10 per cent above
- Seasonal, 44 per cent above

Crop yields:
- Winter wheat, 64 per cent above
- Barley, 26 per cent above
- Milo, 60 per cent above
- Corn, 151 per cent above

In general the season was free from hot winds, periods of drought, and insect pests. Winter wheat and barley suffered a little from a lack of water for a short period preceding the middle of June. Milo was injured to some extent by heavy freezes in late September. Frost-free period, 153 days.

Crop year 1921

Precipitation:
- Annual, 18 per cent above
- Seasonal, 3 per cent above

Crop yields:
- Winter wheat, 24 per cent above
- Barley, 24 per cent below
- Milo, 43 per cent above
- Corn, 12 per cent above

The stand of oats and barley was thinned by a temperature of 8° F. on the 9th of April. Conditions were generally favorable. Winter wheat that had made the heaviest growth suffered some from a lack of water in May. Frost-free period, 164 days.

Crop year 1922

Precipitation:
- Annual, 8 per cent below
- Seasonal, 4 per cent below

Crop yields:
- Winter wheat, 17 per cent above
- Barley, 15 per cent below
- Milo, 23 per cent above
- Corn, 1 per cent above

Winter wheat came through the winter in very weak condition. Ripening was hastened by dry weather in June. Barley was affected to some extent by the same dry period. The yield and quality of corn was lowered by hot, dry weather in August. Milo suffered from dry weather in August and September. Frost-free period, 162 days.

HAYS (KANS.) FIELD STATION

YEAR	INCHES	AUG.	SEPT.	OCT.	NOV	DEC.	JAN	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR	CROP YIELDS		CROP YEAR
1906	4 3 2 1	2.87	3.39	2.94	0.86	0.51	0.64	0.22	0.85	0.11	0.80	4.72	9.09	27.00	W.WHEAT BARLEY KAFIR CORN	11.7 0.0 21.5 6.1	1907
1907	4 3 2 1	2.85	2.06	1.06	0.11	1.76	T	0.92	T	2.18	2.98	6.05	2.82	22.79	W.WHEAT BARLEY KAFIR CORN	20.6 11.7 0.0 6.3	1908
1908	4 3 2 1	5.29	0.74	1.76	1.79	0.03	0.39	0.28	1.16	0.39	1.28	10.04	3.66	26.81	W.WHEAT BARLEY KAFIR CORN	0.0 0.0 13.9 15.0	1909
1909	4 3 2 1	1.37	2.90	1.78	3.55	1.00	0.58	0.26	0.03	0.97	3.88	2.58	2.02	20.92	W.WHEAT BARLEY KAFIR CORN	32.5 24.3 27.8 7.1	1910
1910	4 3 2 1	4.01	0.60	0.32	T	0.14	0.12	2.12	0.14	0.78	2.10	0.85	2.66	14.04	W.WHEAT BARLEY KAFIR CORN	1.3 0.2 1.5 0.0	1911
1911	4 3 2 1	3.44	2.56	0.30	0.14	1.82	0.02	1.98	1.60	1.65	3.40	3.49	0.55	20.95	W.WHEAT BARLEY KAFIR CORN	14.5 26.9 22.7 2.6	1912
1912	4 3 2 1	3.96	1.59	0.56	1.13	0.03	0.36	0.68	0.41	2.97	5.72	3.34	0.55	21.30	W.WHEAT BARLEY KAFIR CORN	7.1 7.1 0.0 0.0	1913
1913	4 3 2 1	0.11	4.64	0.24	0.72	3.11	0.04	0.42	0.15	2.24	3.36	3.13	1.51	19.67	W.WHEAT BARLEY KAFIR CORN	20.8 15.1 9.1 3.3	1914
1914	4 3 2 1	3.01	0.53	1.17	T	0.63	0.68	1.80	1.74	3.84	5.96	5.04	8.13	30.53	W.WHEAT BARLEY KAFIR CORN	17.2 35.7 50.9 17.6	1915
1915	4 3 2 1	3.91	2.88	0.58	0.30	0.04	0.53	0.15	0.31	2.60	1.49	5.87	0.40	19.06	W.WHEAT BARLEY KAFIR CORN	33.2 14.7 6.3 2.3	1916
1916	4 3 2 1	2.03	1.15	1.04	0.02	0.61	0.11	T	0.07	2.07	1.65	2.15	1.07	11.97	W.WHEAT BARLEY KAFIR CORN	5.6 1.3 1.3 1.2	1917
1917	4 3 2 1	5.56	1.54	0.09	1.64	0.15	0.80	1.15	1.71	2.81	4.86	0.60	3.24	24.15	W.WHEAT BARLEY KAFIR CORN	14.3 28.1 2.2 1.4	1918
1918	4 3 2 1	1.81	1.35	2.31	1.10	2.38	T	2.18	0.33	6.01	5.89	2.83	1.34	26.53	W.WHEAT BARLEY KAFIR CORN	15.7 38.7 27.6 4.0	1919
1919	4 3 2 1	0.85	3.28	1.85	1.54	0.16	0.05	0.37	0.30	2.26	3.68	1.93	2.27	18.52	W.WHEAT BARLEY KAFIR CORN	31.3 34.5 58.2 16.5	1920
1920	4 3 2 1	5.63	1.37	3.58	0.73	0.46	0.40	0.10	0.49	3.59	2.64	3.76	3.28	26.03	W.WHEAT BARLEY KAFIR CORN	32.6 29.3 38.3 11.9	1921
1921	4 3 2 1	3.46	0.63	0.06	0.00	0.50	T	0.93	1.71	4.96	3.24	3.56	2.48	21.52	W.WHEAT BARLEY KAFIR CORN	27.6 35.2 17.8 8.5	1922
1922	4 3 2 1	0.59	0.28	0.27	1.28	T	T	0.10	1.04	1.61	4.29	4.44	0.64	14.44	W.WHEAT BARLEY KAFIR CORN	0.0 19.4 17.1 0.0	1923
1923	4 3 2 1	4.02	4.33	4.37	0.29	0.37	0.31	0.26	1.81	0.92	3.26	0.47	1.97	22.38	W.WHEAT BARLEY KAFIR CORN	41.7 37.2 26.4 7.1	1924
AVERAGE		3.04	2.01	1.35	.84	.76	.28	.77	.77	2.28	3.36	3.60	2.53	21.59			
MONTH		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	TOTAL YEAR			

FIG. 32.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Hays (Kans.) Field Station.

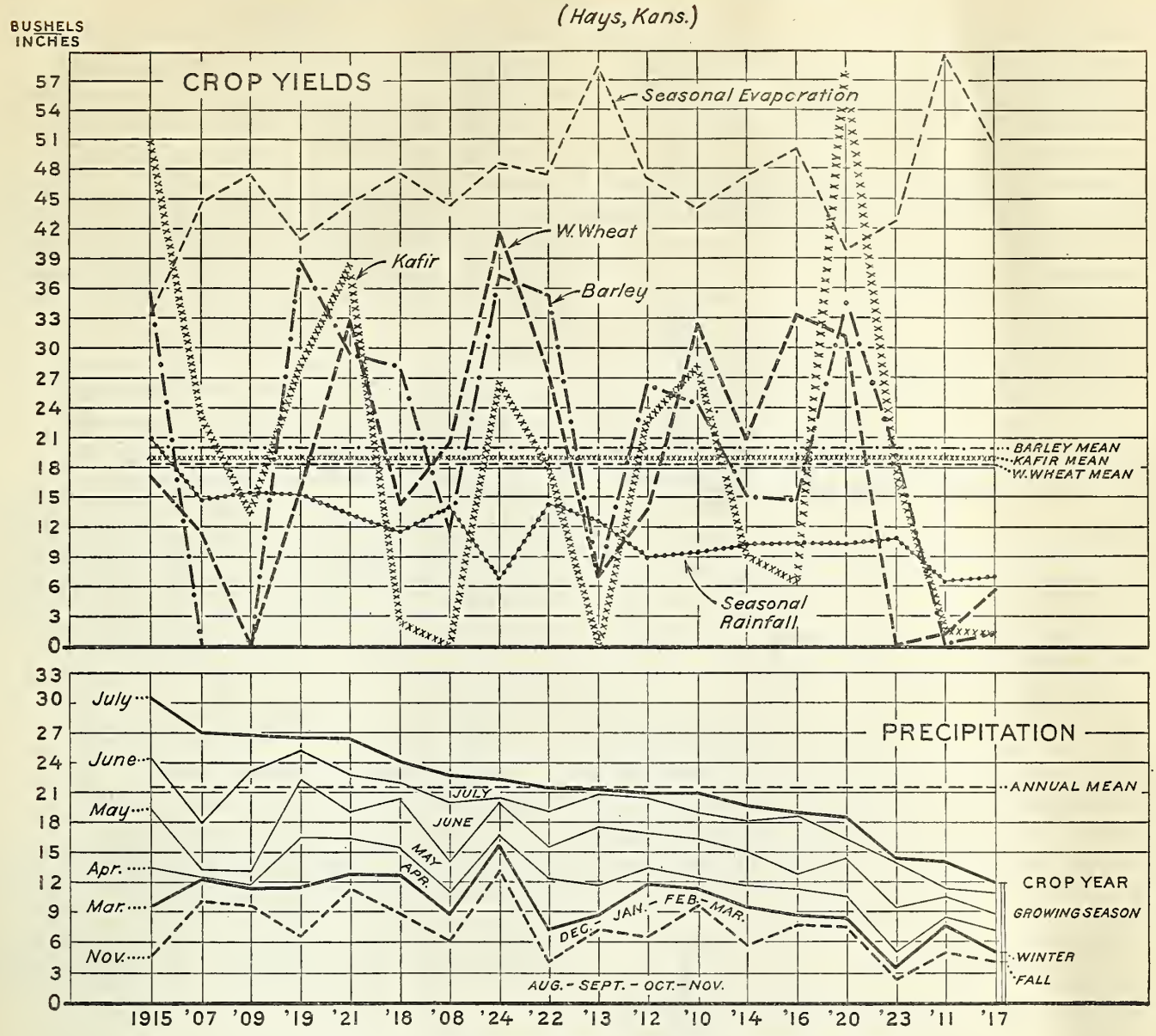


FIG. 33.—Diagram summarizing the relations between rainfall and crop yields at Hays, Kans.

Crop year 1923

Precipitation:
- Annual, 8 per cent above
- Seasonal, 42 per cent above

Crop yields:
- Winter wheat, 71 per cent below
- Barley, 58 per cent above
- Milo, 164 per cent above
- Corn, 120 per cent above

Very little of the winter wheat emerged in the fall and that was very late. The final stand was very poor, weeds offered serious competition, growth was slow, and the wheat finally succumbed to the most severe attack of stem rust ever experienced in the section. Conditions were very favorable to all other crops. Frost-free period, 172 days.

Crop year 1924

Precipitation:
- Annual, 13 per cent below
- Seasonal, 61 per cent below

Crop yields:
- Winter wheat, 16 per cent above
- Barley, 20 per cent below
- Milo, 44 per cent below
- Corn, 60 per cent below

By the middle of May, winter wheat began to show signs of lack of water, and from that time until harvest there was not water enough to overcome the checked habit of growth, but the crop filled well. Spring-sown small grains suffered from poor stands and from a lack of water. The lack of water during the growing season accounted for the low yield of corn. Milo suffered from the same cause. Many plats failed to make a stand. Frost-free period, 137 days.

RESULTS AT HAYS, KANS.

[Altitude, 2,000 feet; 18-year period (figs. 32 and 33)]

Climatic conditions: Mean annual precipitation, 21.59 inches; mean seasonal precipitation, 11.77 inches; mean seasonal evaporation, 46.562 inches.

Average frost-free period, 163 days.

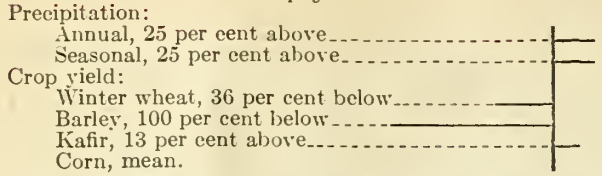
Soil: Clay loam.

Number of crop yields averaged each year: Winter wheat, 40; barley, 15; kafir, 26; corn, 21.

Average annual crop yields per acre: Winter wheat, 18.2 bushels; barley, 19.9 bushels; kafir, 19 bushels; corn, 6.1 bushels.

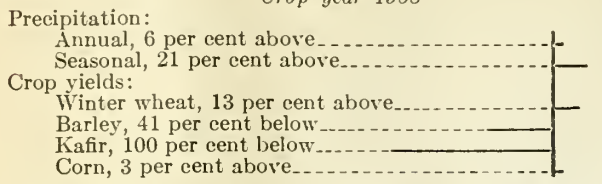
11810°—27——4

Crop year 1907



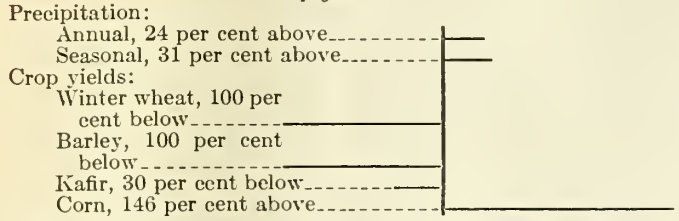
Corn was killed by a freeze on May 27 and replanted June 3. Winter wheat suffered from spring drought. Barley was destroyed by soil blowing and spring drought. Frost-free period, 159 days.

Crop year 1908



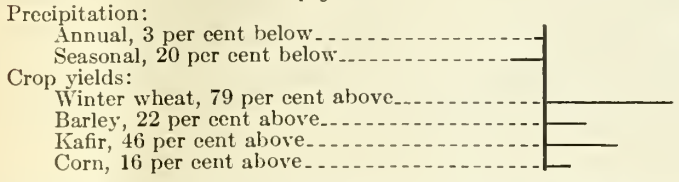
Grasshoppers injured corn, particularly by eating the silks. Barley suffered from drought before harvest. Winter wheat was about normal. Kafir did not germinate; replanted but did not make a stand. Frost-free period, 168 days.

Crop year 1909



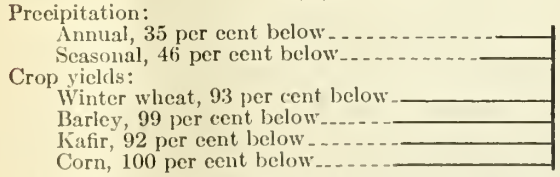
There was long-continued drought in the spring during which small grains suffered much from soil blowing. Small grains were finally destroyed by hail on June 13. Winter wheat on fallow plats located so they were not destroyed by soil blowing was estimated before the hailstorm to promise a yield of 30 bushels. Corn was about a foot high at the time of the hailstorm and only partly recovered from it. Kafir was replanted after the hailstorm and made a fair crop, although it was too late to attain its fullest development. Frost-free period, 164 days.

Crop year 1910



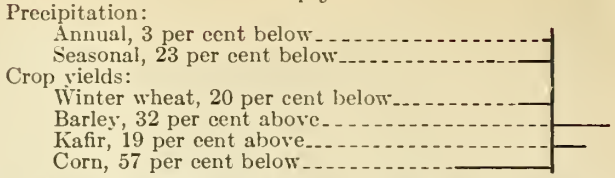
Corn suffered some from drought and was damaged more or less by chinch bugs and grasshoppers, but the most serious damage to it was by hot winds when it was in tassel. These prevented fertilization. Winter wheat suffered a little from drought in April and again just before harvest, which was on June 24. The development of kafir was about normal. Barley suffered a little from drought preceding harvest. Frost-free period, 178 days.

Crop year 1911



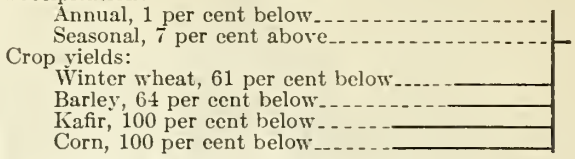
All crops started nicely in the spring, but the rainfall was so light that all the small grains began to suffer early in May. The continued drought—accompanied by high temperatures and hot winds, together with attacks of chinch bugs, grasshoppers, and jack rabbits—damaged the crops to such an extent that all were practically failures, although a little grain was produced on plats fallowed the year before. The loss of the grain sorghums was chiefly due to the chinch bugs, while the drought alone was probably sufficient to account for the greater part of the loss of corn and small grains. Frost-free period, 160 days.

Crop year 1912



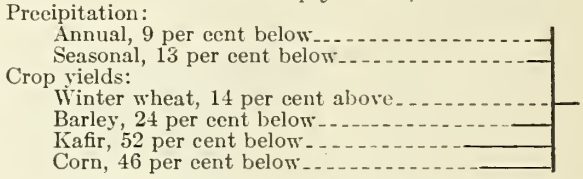
Winter wheat made rank growth until about the middle of May, when it began to suffer from drought and hot winds. It appeared ripe before it headed. Spring grain did not suffer so soon, but dried up before harvest. Barley was also injured by chinch bugs. Corn and the sorghums suffered from chinch bugs and grasshoppers. Corn suffered more than kafir and was also blown down by wind. Frost-free period, 133 days.

Crop year 1913



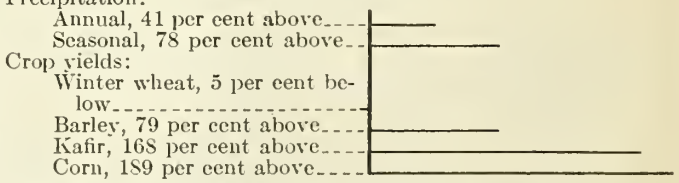
Conditions were favorable for corn until the end of June. Hot winds, grasshoppers, drought, and chinch bugs entirely destroyed it between July 4 and July 15. Drought and hot winds prevented the production of grain, and grasshoppers destroyed the fodder. Winter wheat made a good growth of straw, but drought in the later stages of development greatly reduced the yield of grain. There was much run-off from the rain of May 2. Kafir and milo were destroyed by chinch bugs assisted by grasshoppers. Frost-free period, 188 days.

Crop year 1914



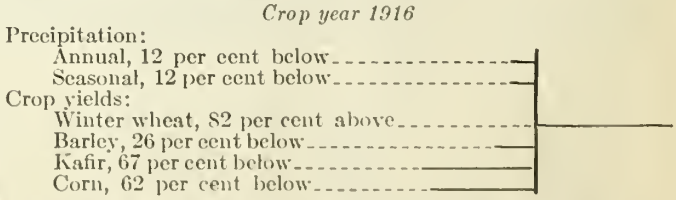
Winter wheat suffered somewhat from drought in May and again in the latter part of June, but yielded above the average. Barley and other spring-sown small grains suffered from drought in June. Kafir grew normally until about the heading stage in the latter part of July. It had then exhausted its supply of soil water. Unbroken save by occasional light showers, the drought continued until the kafir had matured. Hot winds at tasseling time prevented fertilization in corn, and very little grain was formed. Frost-free period, 165 days.

Crop year 1915



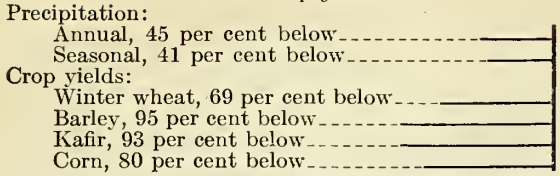
Winter wheat grew very heavy straw, but the grain yield was reduced by lodging and hail damage. Barley was thought to be damaged more than the wheat by the hail, but evidently it recovered better. Conditions were very favorable to both corn and kafir. Frost-free period, 185 days.

Crop year 1916



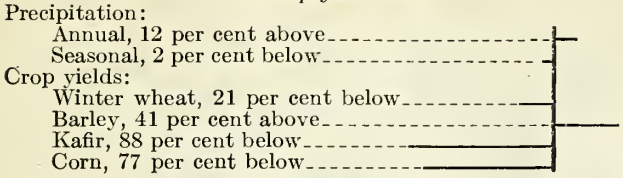
Winter wheat suffered some from drought in May, but conditions were generally favorable for it. Spring-sown small grains suffered serious damage by green bugs. Green bugs, chinch bugs, grasshoppers, and drought were too much for corn and the sorghums. Frost-free period, 149 days.

Crop year 1917



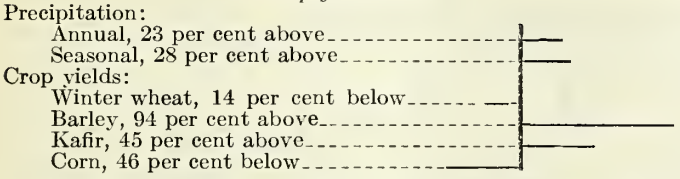
Little or no grain was produced except where planted on fallow. Small grains suffered from drought in June and corn and the sorghums in July. Kafir was so delayed by the drought that it was frosted before much seed matured. Frost-free period, 153 days.

Crop year 1918



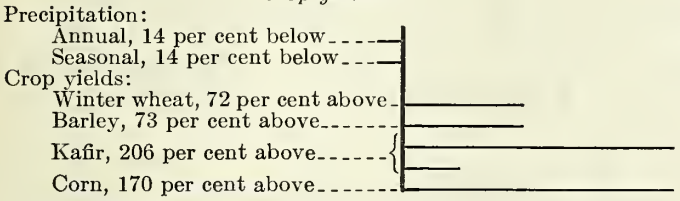
Winter wheat suffered from wind and drought in the middle of May. By June 15 all small grains were suffering severely from drought and drying up rapidly. The drought continued until small grains were harvested. Corn dried up in August without earing, and only a small percentage of the kafir headed. Frost-free period, 142 days.

Crop year 1919



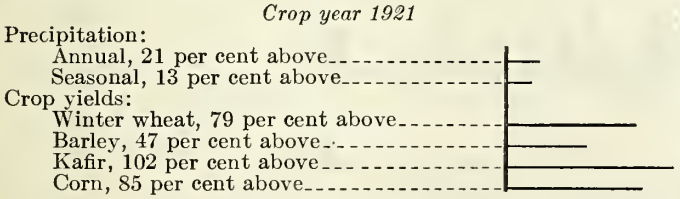
Small grains responded to favorable moisture conditions with a very heavy vegetative growth, but there was practically no rain after June 12 until they were matured or dried up. Both the quantity and the quality were injured. The heavy growth of winter wheat was lodged and injured by hail on May 2. The drought continued until September 17. Corn dried up, and the development of the sorghums were retarded. Frost-free period, 176 days.

Crop year 1920



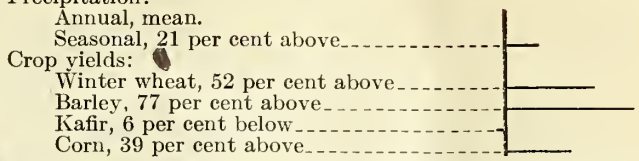
The season of 1920 as a whole was one of the most favorable experienced at this station, and crops yielded far above their averages. Frost-free period, 155 days.

Crop year 1921



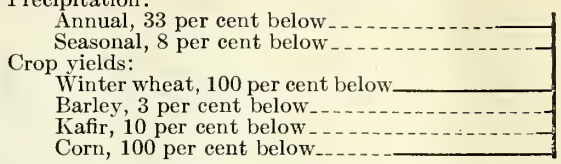
Barley was injured more than other crops by a spring frost and also suffered from a dry spell in the latter part of May. A second drought in the latter part of July and the first part of August checked the development of the grain sorghums, but was not serious in its results. Corn dried up rapidly during this drought period and was practically dead by August 13, when the drought was broken by a heavy rain. Frost-free period, 158 days.

Crop year 1922



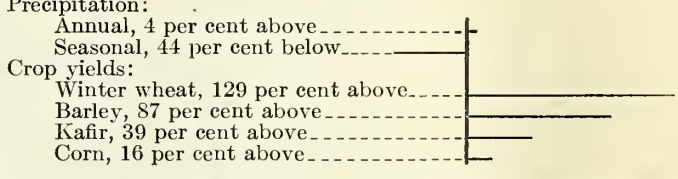
The distribution of the precipitation was very favorable to small grains, as indicated by the yields obtained. It was not, however, so favorable for cultivated crops, as there were no good rains after July 9. Frost-free period, 174 days.

Crop year 1923



The drought which began the previous July continued unbroken until April 24. This made winter wheat too late to develop much of a crop. With no reserve of water in the soil, the seasonal precipitation was not sufficient for the needs of the small grains. The spring-sown grains were dried up during the latter part of June, and finally all spring-sown small grains were completely destroyed by hail June 29. Winter wheat outside of the hail area succumbed to rust. Row crops were badly damaged by the storm. One of the driest Julys in 56 years followed. Corn made no ears. The sorghums recovered from the hail and survived the drought sufficiently well to be able to respond to the August and September rains and produce some fair yields. Frost-free period, 180 days.

Crop year 1924



The precipitation in June was the lowest on record for that month. The soil was well filled with water from the preceding fall, the spring was early, and the average yield of winter wheat was the highest in the history of the station. Its growth was checked somewhat by drought in May, and its maturity was hastened by drought in June. The yield of barley was reduced by chinch bugs. Row crops began to show the lack of water by the last of July, and during August corn was so badly damaged that it made but little grain. Sorghums survived conditions better. Frost-free period, 155 days.

RESULTS AT GARDEN CITY, KANS.

[Altitude, 2,836 feet; 16-year period (figs. 34 and 35)]

Climatic conditions: Mean annual precipitation, 19.01 inches; mean seasonal precipitation, 14.26 inches; mean seasonal evaporation, 52.152 inches.

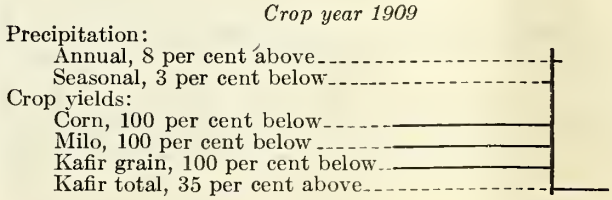
Average frost-free period, 167 days.

Soil: Sandy loam.

Number of crop yields averaged each year: Corn, 17; milo, 13; kafir grain, 23; kafir total, 23.

Average annual crop yields per acre: Corn, 7.9 bushels; milo, 18.1 bushels; kafir grain, 13 bushels; kafir total, 3,776 pounds.

Crop year 1909



The season was very dry until May 20. Some plats of small grains survived and produced straw, but the dry weather in the

GARDEN CITY (KANS.) FIELD STATION

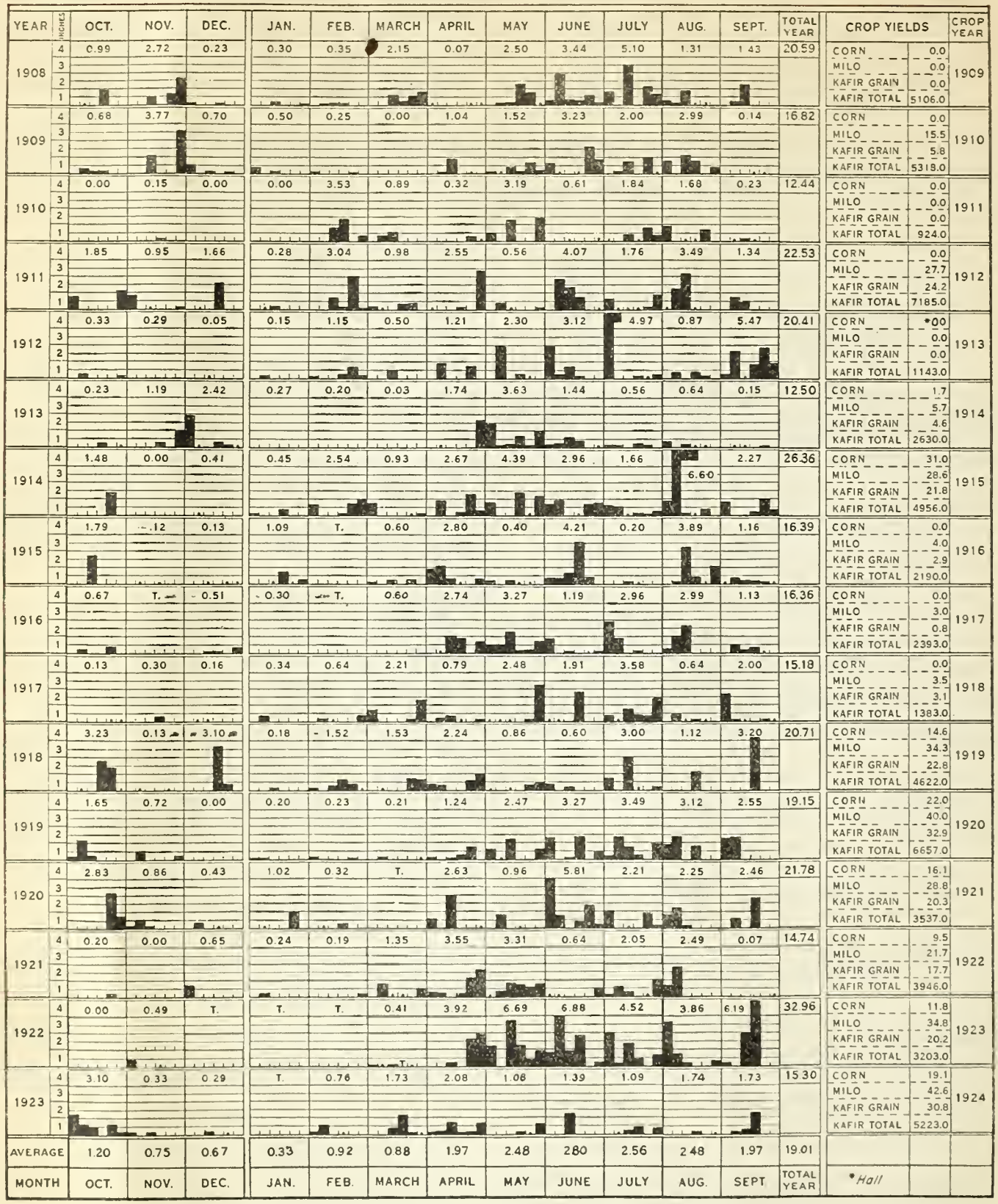


FIG. 34.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Garden City (Kans.) Field Station

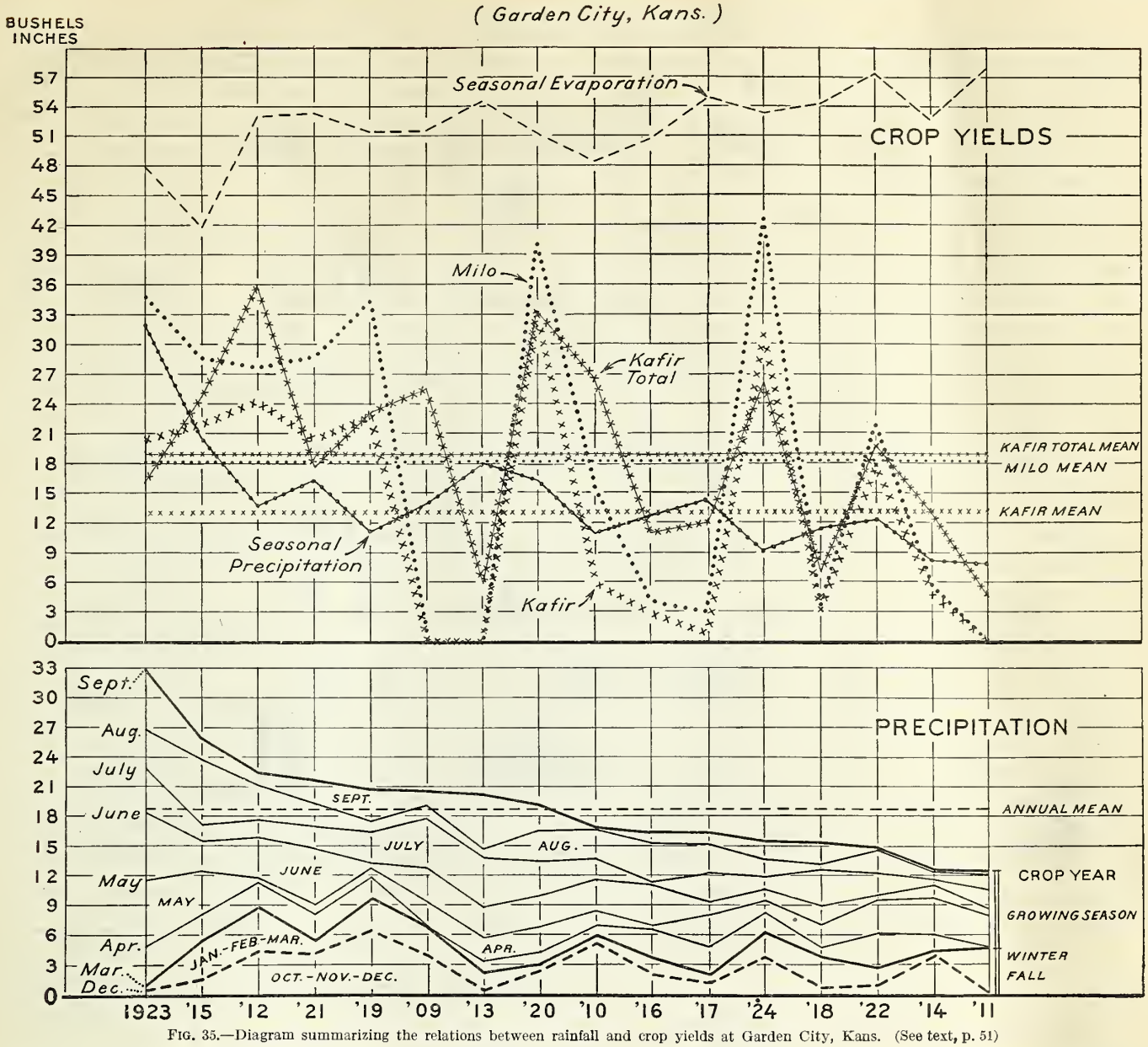


FIG. 35.—Diagram summarizing the relations between rainfall and crop yields at Garden City, Kans. (See text, p. 51)

latter part of June and the first of July prevented it from filling. Corn, kafir, and milo made a good growth of stalks, but drought and hot winds in August prevented the formation of grain. Frost-free period, 164 days.

Crop year 1910

Precipitation:
- Annual, 12 per cent below
- Seasonal, 23 per cent below

Crop yields:
- Corn, 100 per cent below
- Milo, 14 per cent below
- Kafir grain, 55 per cent below
- Kafir total, 41 per cent above

Winter wheat was destroyed in the fall by grasshoppers and jack rabbits. Some of the spring-sown small grain had a good growth of straw, but the water supply was not sufficient to mature any of them properly. Corn made a good growth of fodder, but did not have water enough or was unable to withstand the hot winds sufficiently to set grain. Kafir and milo had good stands and a heavy growth of stalks, but the September drought interfered with the development of grain. Frost-free period, 163 days.

Crop year 1911

Precipitation:
- Annual, 35 per cent below
- Seasonal, 45 per cent below

Crop yields:
- Corn, 100 per cent below
- Milo, 100 per cent below
- Kafir grain, 100 per cent below
- Kafir total, 75 per cent below

Crops were unable to survive the drought and produce grain. Weekly notes show that most of the small grains were gone by the middle of June, that corn and the sorghums were beginning to suffer decidedly by the first of July, that corn was fired beyond the possibility of recovery by July 22, and that most of the sorghums were practically dead by August 19. Frost-free period, 159 days.

WOODWARD (OKLA.) FIELD STATION

YEAR	INCHES	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL YEAR	CROP YIELDS		CROP YEAR
1914	4	1.96	0.06	0.77	1.17	3.44	1.45	6.53	5.29	2.43	3.14	3.62	5.74	35.60	W.WHEAT	27.4	1915
	3														MILO	35.4	
	2														KAFIR GRAIN	37.2	
	1														KAFIR TOTAL	8024.0	
1915	4	2.36	0.55	0.06	1.50	0.03	0.82	1.78	1.70	10.26	0.00	1.02	2.34	22.42	W.WHEAT	2.6	1916
	3														MILO	9.2	
	2														KAFIR GRAIN	5.3	
	1														KAFIR TOTAL	3330.0	
1916	4	1.71	0.75	0.60	0.20	0.20	0.10	1.58	1.03	1.37	1.13	6.65	2.72	18.04	W.WHEAT	9.0	1917
	3														MILO	23.3	
	2														KAFIR GRAIN	24.9	
	1														KAFIR TOTAL	7392.0	
1917	4	0.05	0.67	0.01	1.60	0.29	2.09	2.22	4.00	1.91	0.73	1.35	1.24	16.16	W.WHEAT	7.8	1918
	3														MILO	6.2	
	2														KAFIR GRAIN	6.9	
	1														KAFIR TOTAL	2705.0	
1918	4	3.35	1.53	2.92	0.06	1.53	1.94	4.10	4.29	2.22	1.35	1.87	0.63	25.79	W.WHEAT	14.7	1919
	3														MILO	22.3	
	2														KAFIR GRAIN	20.3	
	1														KAFIR TOTAL	4608.0	
1919	4	1.85	2.37	0.00	1.03	0.07	0.61	1.06	3.40	1.29	4.69	3.00	5.01	24.38	W.WHEAT	13.5	1920
	3														MILO	21.3	
	2														KAFIR GRAIN	32.7	
	1														KAFIR TOTAL	8007.0	
1920	4	2.55	1.32	1.53	2.22	0.61	1.33	1.80	1.91	5.78	2.50	5.11	2.94	29.60	W.WHEAT	28.4	1921
	3														MILO	30.2	
	2														KAFIR GRAIN	30.4	
	1														KAFIR TOTAL	6108.0	
1921	4	0.01	0.00	0.11	1.02	0.96	5.08	2.97	3.69	0.18	1.07	2.31	2.83	20.23	W.WHEAT	25.0	1922
	3														MILO	11.0	
	2														KAFIR GRAIN	9.5	
	1														KAFIR TOTAL	3613.0	
1922	4	0.74	1.15	0.00	0.00	0.06	1.86	2.32	8.11	4.20	0.69	0.39	9.33	28.85	W.WHEAT	18.3	1923
	3														MILO	5.2	
	2														KAFIR GRAIN	13.5	
	1														KAFIR TOTAL	3555.0	
1923	4		0.89	0.84	0.03	0.81	2.96	3.14	0.78	1.46	3.07	3.40	3.22	32.59	W.WHEAT	19.0	1924
	3														MILO	27.4	
	2	11.99													KAFIR GRAIN	27.3	
	1														KAFIR TOTAL	4061.0	
AVERAGE		2.66	0.93	0.68	0.88	0.80	1.82	2.75	3.42	3.11	1.84	2.87	3.61	25.37			
MONTH		OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL YEAR			

FIG. 36.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Woodward (Okla.) Field Station

Crop year 1912

Precipitation:
- Annual, 19 per cent above
- Seasonal, 3 per cent below

Crop yields:
- Corn, 100 per cent below
- Milo, 53 per cent above
- Kafir grain, 86 per cent above
- Kafir total, 90 per cent above

The season of 1912 was especially favorable for all crops except corn, which fired badly at tasseling time the latter part of July and did not set ears. Frost-free period, 156 days.

Crop year 1913

Precipitation:
- Annual, 7 per cent above
- Seasonal, 26 per cent above

Crop yields:
- Corn, 100 per cent below
- Milo, 100 per cent below
- Kafir grain, 100 per cent below
- Kafir total, 70 per cent below

Although the precipitation was above the mean, the season was hot and dry. Most of the July precipitation of 4.97 inches came in a single hail and rain storm, and run-off was heavy. The September rainfall of nearly 5½ inches came too late to help crops. Winter wheat was eaten by birds in the fall. Spring-sown small grains on fallow promised a crop until July 4, when they were destroyed by a hailstorm. Corn was killed at the same time. The sorghums were so badly injured that they were not able to recover enough to make a crop in the hot dry weather that followed, continuing through July and August. Frost-free period, 168 days.

Crop year 1914

Precipitation:
- Annual, 34 per cent below
- Seasonal, 43 per cent below

Crop yields:
- Corn, 78 per cent below
- Milo, 68 per cent below
- Kafir grain, 65 per cent below
- Kafir total, 30 per cent below

The distribution of the precipitation favored the small grains. Winter wheat was harvested by June 20 without serious suffering for water. Spring-sown small grains were later and suffered more. The continued drought of July, August, and September was too much for corn and the sorghums. Frost-free period, 185 days.

Crop year 1915

Precipitation:
- Annual, 39 per cent above
- Seasonal, 44 per cent above

Crop yields:
- Corn, 292 per cent above
- Milo, 58 per cent above
- Kafir grain, 68 per cent above
- Kafir total, 31 per cent above

Small grains and corn produced profitable crops for the first time. The corn crop did not suffer serious injury from

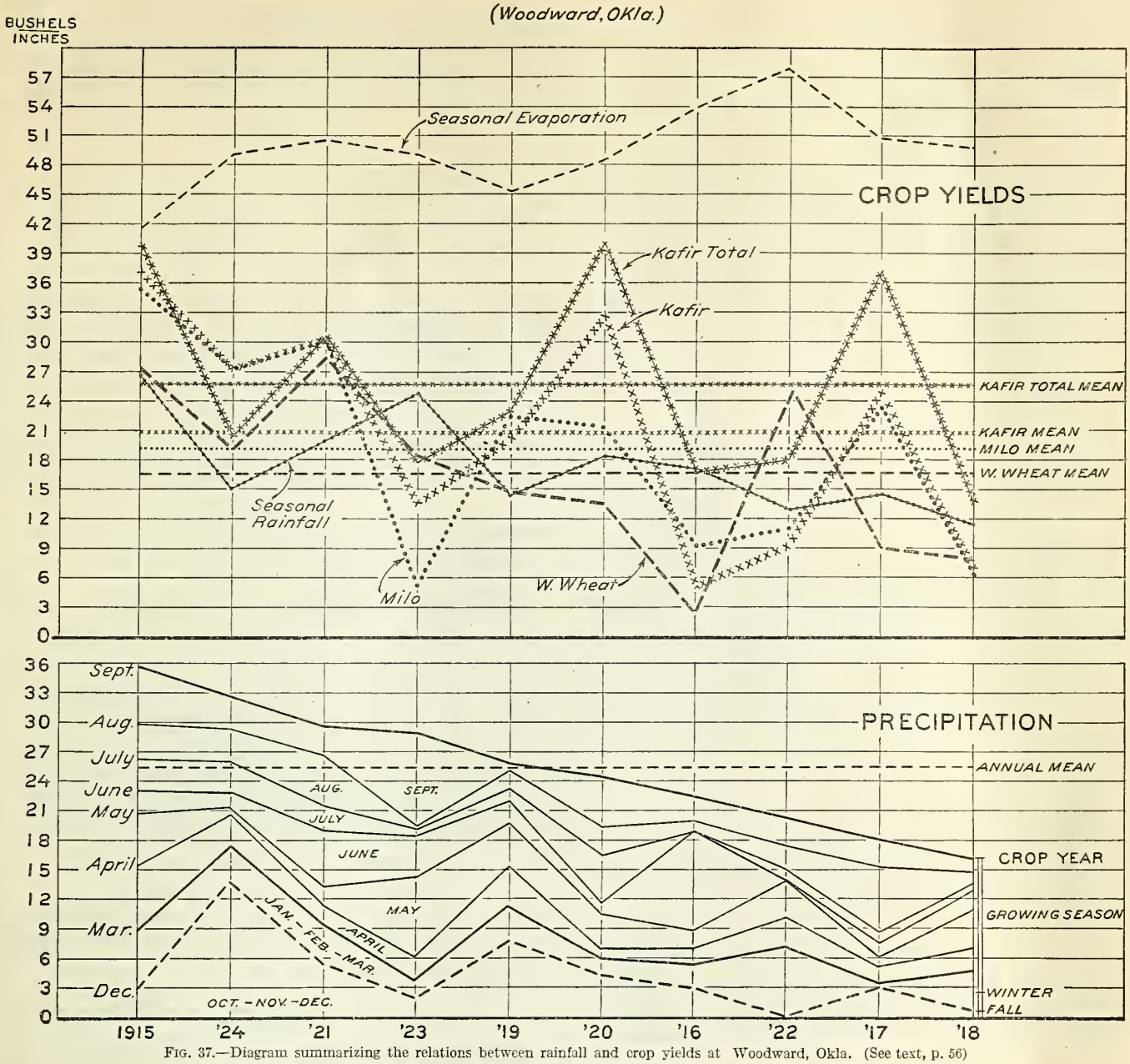


FIG. 37.—Diagram summarizing the relations between rainfall and crop yields at Woodward, Okla. (See text, p. 56)

lack of water at any time during the season. Water conditions were favorable to the sorghums, but temperatures were too low during the greater part of the season for the best results with these crops. Only about 25 per cent of the kafir matured fully. Frost-free period, 185 days.

Crop year 1916

Precipitation:
- Annual, 14 per cent below
- Seasonal, 11 per cent below

Crop yields:
- Corn, 100 per cent below
- Milo, 78 per cent below
- Kafir grain, 78 per cent below
- Kafir total, 42 per cent below

General climatic conditions throughout the season were very adverse to the growth of all crops. From about the middle of June to the middle of August there were no rains of value to crops. About the only winter wheat to harvest was on fallow. Most of the spring-sown small grains were crowded out early in the season by Russian thistles. Corn began to fire badly about the middle of July and dried up, being harvested early in August. The dry condition of the surface soil made it difficult to obtain good stands of the sorghums. It was necessary to replant many of the plats, and some of the seed did not germinate until after the heavy rain of August 15. Rains came too late and in insufficient quantities to enable any of the sorghums except those on fallow to produce much grain. The little that was threshed was immature and of poor quality. Frost-free period, 169 days.

Crop year 1917

Precipitation:
- Annual, 14 per cent below
- Seasonal, mean.

Crop yields:
- Corn, 100 per cent below
- Milo, 83 per cent below
- Kafir grain, 94 per cent below
- Kafir total, 37 per cent below

Winter wheat failed to survive the dry winter and spring. All spring-sown small grains were complete failures. A dry June with hot winds dried them up without heading or prevented the heads from filling. There was a severe hailstorm on June 5, but the small grains were small and apparently soon recovered from the injury. The first growth of corn was checked by the hail. By August 1 drought had dried it up and chinch bugs had eaten much of it. The sorghum crops were damaged by dry weather and chinch bugs to the extent that they produced grain only when planted on fallow. Frost-free period, 154 days.

Crop year 1918

Precipitation:
- Annual, 20 per cent below
- Seasonal, 20 per cent below

Crop yields:
- Corn, 100 per cent below
- Milo, 81 per cent below
- Kafir grain, 76 per cent below
- Kafir total, 63 per cent below

Winter wheat and rye failed to survive the winter. Spring-sown small grains failed almost completely as a result of drought and hot winds. Only a few plats of wheat on fallow were harvested. A shortage of water checked the growth of corn before maturity, and no grain was produced. Grasshoppers damaged it considerably. Poor stands of sorghums were obtained, and they made slow and irregular growth in the early season. They ran out of water later and produced practically no grain and but little forage. Frost-free period, 179 days.

Crop year 1919

Precipitation:
- Annual, 9 per cent above
- Seasonal, 23 per cent below

Crop yields:
- Corn, 85 per cent above
- Milo, 90 per cent above
- Kafir grain, 75 per cent above
- Kafir total, 22 per cent above

The ground was covered with snow from December until March, and there was a good supply of water in the soil in the spring. Winter wheat suffered somewhat from a lack of water in May and June, but yielded more than its average. Spring grains did well until about the middle of June, when hot winds and a lack of water dried them so that only poor yields of light and shrunken grain were obtained. Dry weather during the summer reduced the yield of corn. The corn earworm attacked all the ears that were formed, and as a result the quality was poor. The sorghums did not suffer much from a lack of water during the summer and had good, well-filled heads. Frost-free period, 176 days.

Crop year 1920

Precipitation:
- Annual, 1 per cent above
- Seasonal, 13 per cent above

Crop yields:
- Corn, 178 per cent above
- Milo, 121 per cent above
- Kafir grain, 153 per cent above
- Kafir total, 76 per cent above

Winter wheat was killed by late freezes and high winds in April, and spring-sown small grains suffered from a lack of water in June, but corn and the sorghums developed under exceptionally favorable conditions and yielded well. The quality and probably the yield of corn suffered from the usual ravages of the corn earworm. Frost-free period, 155 days.

Crop year 1921

Precipitation:
- Annual, 15 per cent above
- Seasonal, 14 per cent above

Crop yields:
- Corn, 104 per cent above
- Milo, 59 per cent above
- Kafir grain, 56 per cent above
- Kafir total, 6 per cent below

Work with spring grains was discontinued except one plat of each. Winter wheat was injured by late freezes and high winds in April. The yield of corn was greatly reduced by hot winds in August. The grain was of poor quality and badly infested with the corn earworms. Milo and kafir were injured considerably by hot winds and drought in August when they were at about the heading stage. Frost-free period, 174 days.

Crop year 1922

Precipitation:
- Annual, 22 per cent below
- Seasonal, 15 per cent below

Crop yields:
- Corn, 20 per cent above
- Milo, 20 per cent above
- Kafir grain, 36 per cent above
- Kafir total, 5 per cent above

Conditions in 1922 were favorable to the production of winter wheat. All corn plats were badly burned by the end of July, and yields were small and quality poor. After August 8 there was almost no precipitation during the growing season. High temperatures and the lack of water in the latter part of August and in September reduced the yields of sorghums. Frost-free period, 171 days.

Crop year 1923

Precipitation:
- Annual, 73 per cent above
- Seasonal, 125 per cent above

Crop yields:
- Corn, 49 per cent above
- Milo, 92 per cent above
- Kafir grain, 53 per cent above
- Kafir total, 15 per cent below

The drought beginning in August, 1922, was not broken until April 26. Beginning with the latter date and continuing through the season, there was much wet weather. There were many torrential rains and much run-off. The dry fall preceding prevented a stand of winter wheat. Spring-sown small grains did not produce satisfactory yields. Wet weather delayed the planting of corn and the sorghums until later than usual. They were severely damaged by hail on August 4. Corn did not recover as well as the sorghums. Kafir did not recover as well as milo. The quality of the sorghums was injured by wet weather at and after harvest time. Frost-free period, 182 days.

Crop year 1924

Precipitation:
- Annual, 20 per cent below
- Seasonal, 36 per cent below

Crop yields:
- Corn, 142 per cent above
- Milo, 135 per cent above
- Kafir grain, 137 per cent above
- Kafir total, 38 per cent above

The soil was well filled with water from the previous year, the rainfall was well distributed, and no long period of drought was recorded. The yield of winter wheat was one of the best on record at the station. Corn was damaged to some extent by a hot wind on June 18, but the plants were so small that they soon recovered. Milo made the highest average yield recorded at the station. The average yield of kafir was lowered somewhat by the poor yield of listed plats, which washed so badly that it was necessary to replant one. Frost-free period, 137 days.

RESULTS AT WOODWARD, OKLA.

[Altitude, 1,893 feet; 10-year period (figs. 36 and 37)]

Climatic conditions: Mean annual precipitation, 25.37 inches; mean seasonal precipitation, 17.60 inches; mean seasonal evaporation, 49.680 inches.

Average frost-free period, 204 days.

Soil: Loamy sand.

Number of crop yields averaged each year: Winter wheat, 20; milo, 25; kafir grain, 32; kafir total, 32.

Average annual crop yields per acre: Winter wheat, 16.6 bushels; milo, 19.2 bushels; kafir grain, 20.8 bushels; kafir total, 5,140 pounds.

Crop year 1915

Precipitation:
- Annual, 40 per cent above
- Seasonal, 52 per cent above

Crop yields;
- Winter wheat, 65 per cent above
- Milo, 84 per cent above
- Kafir grain, 79 per cent above
- Kafir total, 56 per cent above

Cold, wet weather made replanting of most of the grain sorghums necessary. The final stand, especially of milo, was poor. This was partly caused by moles (pine mice?). Sorghums were very late in maturing. Frost-free period, 225 days.

Crop year 1916

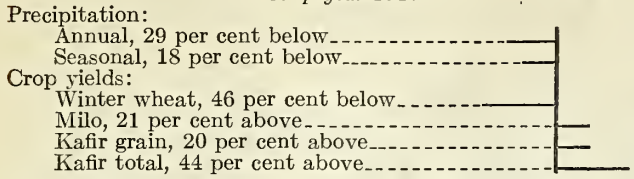
Precipitation:
- Annual, 12 per cent below
- Seasonal, 3 per cent below

Crop yields:
- Winter wheat, 84 per cent below
- Milo, 52 per cent below
- Kafir grain, 75 per cent below
- Kafir total, 35 per cent below

Over half of the precipitation for the year fell in the 30 days from May 26 to June 24, inclusive. Following the latter date

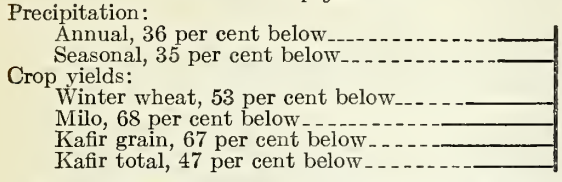
there was no rainfall until August 7. The only good crop was broomcorn. Winter wheat suffered from the May drought and was injured an estimated 25 per cent by hail. Corn and the sorghums suffered from the drought beginning June 24 and continuing with little relief through the season. Milo also suffered from chinch bugs. Frost-free period, 193 days.

Crop year 1917



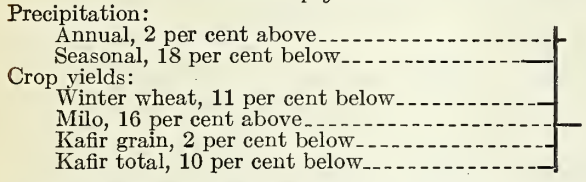
The rainfall previous to August 7 was very deficient. This resulted in the failure of corn and spring-sown small grains and in a low yield of winter wheat. Plentiful rains began about the time the sorghums were heading, and good crops of them were matured. Frost-free period, 190 days.

Crop year 1918



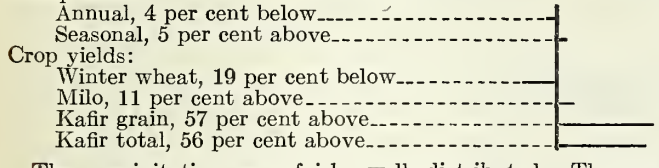
This was the driest year in the history of the station and the yields of all crops were low. Frost-free period, 200 days.

Crop year 1919



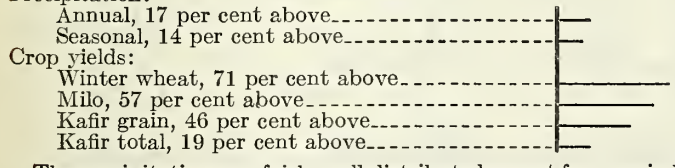
The season was very late, active field work not beginning until in May, at which time there was ample moisture in the soil. The water supply was scanty after July 1, and conditions became critical a number of times, but were sufficiently relieved each time to allow crops to mature normal yields. Frost-free period, 231 days.

Crop year 1920



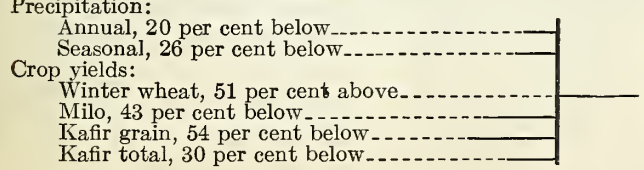
The precipitation was fairly well distributed. The most pronounced dry period was in the latter part of July and the first of August. Milo appeared to suffer more than other crops. The average yield of wheat was reduced by soil blowing and cultivation to prevent blowing. Frost-free period, 202 days.

Crop year 1921



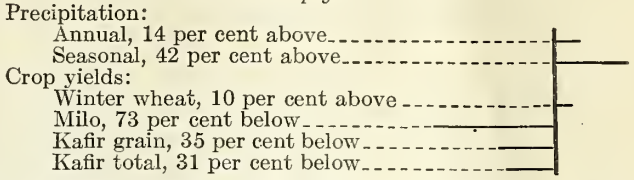
The precipitation was fairly well distributed except for a period in the latter part of July and the first of August, when crops suffered slightly. Frost-free period, 206 days.

Crop year 1922



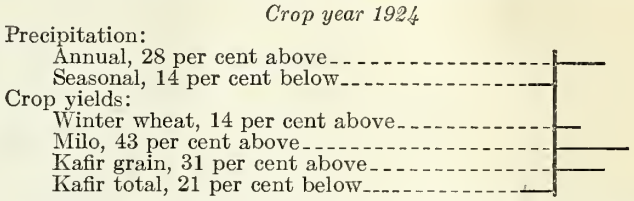
The dry fall gave winter wheat a poor start on most methods, but excessive precipitation in the spring enabled it to mature a good crop. Rainfall during the growing season for cultivated crops was not sufficient for their needs and yields were very low. Temperatures were very high and evaporation the highest recorded at the station. Frost-free period, 174 days.

Crop year 1923



Climatic conditions were very unfavorable to most crops. The total precipitation was high, but its distribution was bad. From June 19 to September 10 it amounted to only 1.22 inches. Winter wheat ripened June 15. It was not well filled. The lack of rain during the growing season for other crops resulted in very poor yields. Frost-free period, 205 days.

Crop year 1924



The crop-year precipitation was very high, but 11.99 inches of it came in October, 1923. The seasonal precipitation was below normal, but its distribution made conditions fairly favorable for most crops. Frost-free period, 210 days.

RESULTS AT DALHART, TEX.

[Altitude, 3,978 feet; 16-year period (figs. 38 and 39)]

Climatic conditions: Mean annual precipitation, 18.68 inches; mean seasonal precipitation, 14.43 inches; mean seasonal evaporation, 51.828 inches.

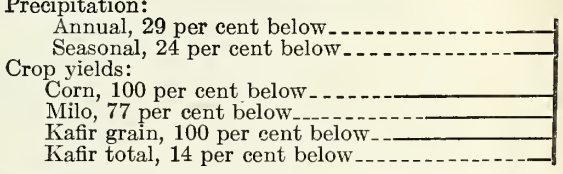
Average frost-free period, 177 days.

Soil: Sandy loam.

Number of crop yields averaged each year: Corn, 17; milo, 19; kafir grain, 16; kafir total, 16.

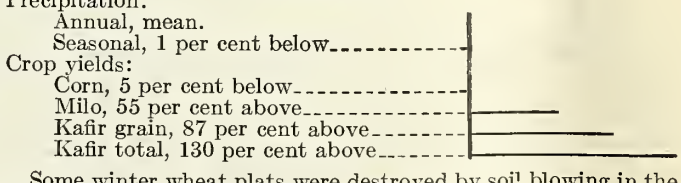
Average annual crop yields per acre: Corn, 13.4 bushels; milo, 23.1 bushels; kafir grain, 19.1 bushels; kafir total, 5,819 pounds.

Crop year 1909



The soil was very dry. Winter wheat did not survive. Spring grains on most methods were ruined by the drought, and their destruction was completed by hail on June 11. Corn was 8 to 10 inches tall at the time of the hail and was badly cut, but made a rapid recovery. About the time it began to suffer from drought it was ruined by a high wind and temperature of 104° F. Milo and kafir were not seriously damaged by the hail. They began to show effects of drought about August 1. Most of them did not head. Frost-free period, 159 days.

Crop year 1910



Some winter wheat plats were destroyed by soil blowing in the winter and the remainder by hail on May 21. Spring grains were killed by soil blowing, were reseeded, and the second planting was ruined by hail. Corn and the sorghums were not planted until the last of May and encountered generally favorable conditions. Plats by some methods suffered from drought for a few days in July and more seriously in September. Frost-free period, 178 days.

DALHART (TEX.) FIELD STATION

YEAR	INCHES	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL YEAR	CROP YIELDS		CROP YEAR
1908	4	0.29	0.93	0.06	T.	0.28	0.71	0.18	1.70	5.10	1.27	0.65	2.12	13.29	CORN	0.0	1909
	3														MILO	5.4	
	2														KAFIR GRAIN	0.0	
	1														KAFIR TOTAL	5030.0	
1909	4	2.60	1.21	0.15	0.20	0.03	0.12	1.51	2.96	4.04	2.48	3.28	0.05	18.63	CORN	12.7	1910
	3														MILO	35.8	
	2														KAFIR GRAIN	35.8	
	1														KAFIR TOTAL	13363.0	
1910	4	0.00	0.07	0.02	0.00	0.54	0.43	0.59	3.37	0.28	3.65	1.87	0.58	11.40	CORN	0.7	1911
	3														MILO	12.7	
	2														KAFIR GRAIN	8.5	
	1														KAFIR TOTAL	4510.0	
1911	4	1.72	0.25	1.28	0.00	1.30	0.76	2.56	2.37	3.36	1.68	2.64	1.98	19.90	CORN	13.0	1912
	3														MILO	34.9	
	2														KAFIR GRAIN	8.4	
	1														KAFIR TOTAL	6204.0	
1912	4	0.05	0.00	0.03	0.06	0.14	0.02	0.88	2.35	1.29	0.85	1.50	1.45	8.62	CORN	0.0	1913
	3														MILO	1.7	
	2														KAFIR GRAIN	3.5	
	1														KAFIR TOTAL	3158.0	
1913	4	0.19	1.78	3.18	0.05	T.	T.	3.98	7.29	3.65	2.58	1.38	0.32	24.40	CORN	23.3	1914
	3														MILO	50.2	
	2														KAFIR GRAIN	34.6	
	1														KAFIR TOTAL	8664.0	
1914	4	3.00	0.00	0.56	0.19	0.72	0.42	5.15	2.58	2.15	3.70	2.11	1.21	21.79	CORN	45.6	1915
	3														MILO	36.9	
	2														KAFIR GRAIN	38.7	
	1														KAFIR TOTAL	7894.0	
1915	4	2.60	0.10	0.01	0.44	0.00	0.12	1.49	0.69	4.42	2.55	3.45	0.72	16.59	CORN	8.7	1916
	3														MILO	17.1	
	2														KAFIR GRAIN	13.3	
	1														KAFIR TOTAL	4911.0	
1916	4	0.22	0.03	0.37	0.14	0.09	0.03	0.37	2.70	0.93	1.64	2.28	1.28	10.08	CORN	0.8	1917
	3														MILO	8.7	
	2														KAFIR GRAIN	3.0	
	1														KAFIR TOTAL	2044.0	
1917	4	0.31	1.02	0.00	0.27	0.05	2.85	0.89	4.87	1.23	1.49	1.67	1.49	16.14	CORN	0.0	1918
	3														MILO	16.1	
	2														KAFIR GRAIN	11.2	
	1														KAFIR TOTAL	3309.0	
1918	4	1.87	0.25	1.74	0.09	0.96	3.18	3.48	2.75	1.88	2.41	3.45	5.12	27.18	CORN	14.0	1919
	3														MILO	34.3	
	2														KAFIR GRAIN	29.6	
	1														KAFIR TOTAL	5124.0	
1919	4	2.50	1.14	T.	0.36	0.43	0.05	0.32	3.25	6.81	2.56	1.33	0.81	19.56	CORN	19.2	1920
	3														MILO	26.1	
	2														KAFIR GRAIN	22.2	
	1														KAFIR TOTAL	5638.0	
1920	4	4.49	0.34	0.08	1.80	0.08	0.15	0.76	3.70	5.82	5.12	0.69	0.04	23.07	CORN	23.9	1921
	3														MILO	23.3	
	2														KAFIR GRAIN	24.8	
	1														KAFIR TOTAL	5444.0	
1921	4	0.54	0.00	0.26	0.37	0.67	0.73	5.20	5.06	3.40	1.57	1.88	0.52	20.20	CORN	9.0	1922
	3														MILO	20.8	
	2														KAFIR GRAIN	15.9	
	1														KAFIR TOTAL	4460.0	
1922	4	0.15	0.36	0.02	0.00	1.03	1.72	4.09	1.78	6.05	0.87	6.92	2.10	25.09	CORN	19.5	1923
	3														MILO	22.7	
	2														KAFIR GRAIN	26.7	
	1														KAFIR TOTAL	7470.0	
1923	4	6.29	1.23	1.32	0.05	0.09	1.61	1.16	2.44	0.69	1.32	5.00	1.72	22.92	CORN	23.7	1924
	3														MILO	22.6	
	2														KAFIR GRAIN	29.3	
	1														KAFIR TOTAL	5873.0	
AVERAGE		1.68	0.54	0.57	0.25	0.40	0.81	2.04	3.12	3.19	2.23	2.51	1.34	18.68			
MONTH		OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL YEAR			

FIG. 38.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Dalhart (Tex.) Field Station

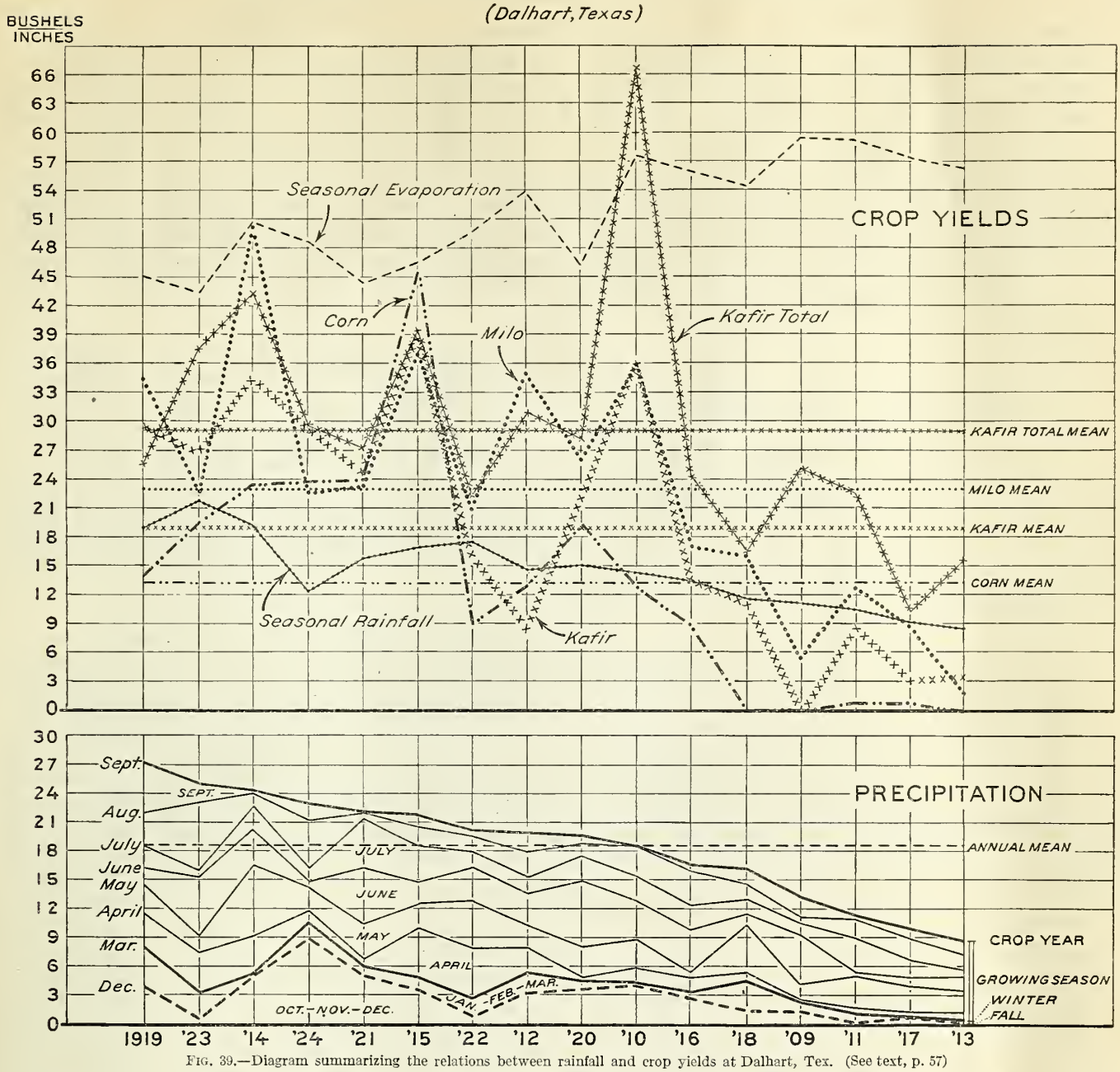


FIG. 39.—Diagram summarizing the relations between rainfall and crop yields at Dalhart, Tex. (See text, p. 57)

Crop year 1911

Precipitation:
- Annual, 39 per cent below
- Seasonal, 28 per cent below

Crop yields:
- Corn, 95 per cent below
- Milo, 45 per cent below
- Kafir grain, 55 per cent below
- Kafir total, 22 per cent below

The low yields in 1911 were the direct result of drought. The season started under very adverse conditions. The precipitation for the eight months from September to April, inclusive, was only 1.70 inches. The May rainfall was sufficient for itself, but not to overcome the deficiency in June. Small grains were almost destroyed by hot winds on June 7 and 8. Only a few plats of oats on fallow headed, and they did not fill. Corn suffered more than the sorghums in the drought preceding the rains in July. Frost-free period, 169 days.

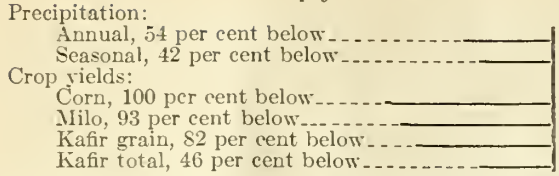
Crop year 1912

Precipitation:
- Annual, 7 per cent above
- Seasonal, 1 per cent above

Crop yields:
- Corn, 3 per cent below
- Milo, 51 per cent above
- Kafir grain, 56 per cent below
- Kafir total, 7 per cent above

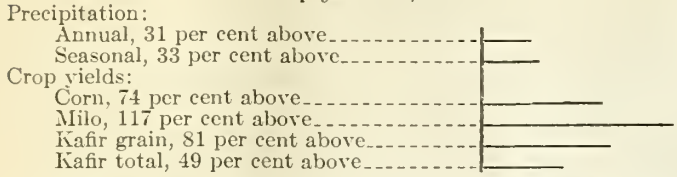
The season opened with more than the usual amount of water in the soil. With the rains that fell during the growing season this carried most of the cultivated crops through to maturity with little damage from drought. The small grains suffered from soil blowing, but promised fair yields when they were destroyed in the milk stage by hail on June 17. Cultivated crops were young and recovered from the hail. The variety of Standard kafir used was too late for the cool season. Frost-free period, 198 days.

Crop year 1913



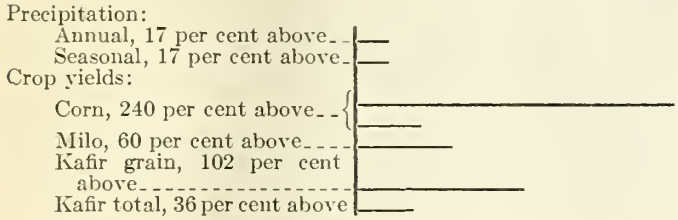
The precipitation for both the crop year and the season of 1913 was the lowest in the history of the station. This was doubtless the cause for an almost complete crop failure, since conditions were otherwise normal. The only method that provided water stored from the previous season was fallow, and the only grain produced was by this method. Frost-free period, 168 days.

Crop year 1914



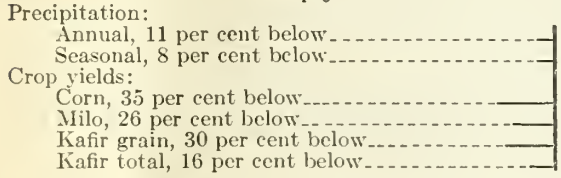
All things considered, the season was one of the most favorable to crop production in the history of the station. By May 1 the soil was wet to a depth of about 8 feet. Frost-free period, 178 days.

Crop year 1915



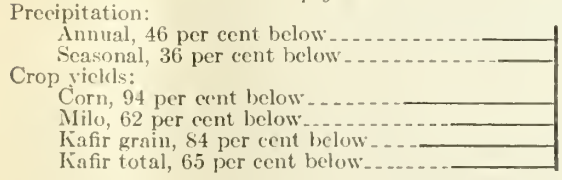
The season was very favorable. The temperature was low. The yields of small grains were light, but every plat seeded produced some grain. The corn yields were the highest in the history of the station. The yields of the grain sorghums were also among the highest obtained. None of the cultivated crops suffered at any time from a lack of water. Frost-free period, 152 days.

Crop year 1916



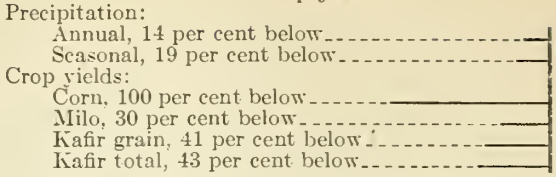
It was very dry until June, and crops suffered again from drought in July and the first of August. The August rainfall enabled the sorghums to make fair crops. Low yields were the direct results of a deficient water supply, but on the other hand the distribution of the deficient supply prevented failures. Frost-free period, 170 days.

Crop year 1917



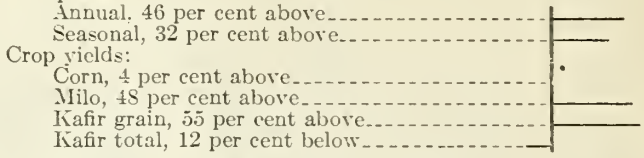
The season of 1917 was about two weeks later than the average. The drought was extreme and continued throughout the season. Most of the plats of small grain were destroyed by a sand storm on May 25. Those that survived the storm dried up a few weeks later. Corn was the only one of the cultivated crops that it was not necessary to replant before a stand was secured. The yield of corn was very light, and the only grain produced by kafir and milo was where they were planted on fallow. Frost-free period, 158 days.

Crop year 1918



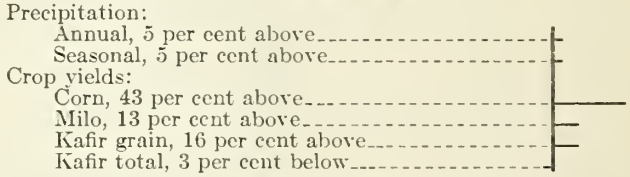
The low yields were the results of deficient precipitation. Small grains all failed; corn was past recovery and the production of grain by it impossible before the end of July; and some of the earliest plantings of sorghums were definite failures before the rains in early August, but later plantings were able to recover and make fair crops. Frost-free period, 178 days.

Crop year 1919



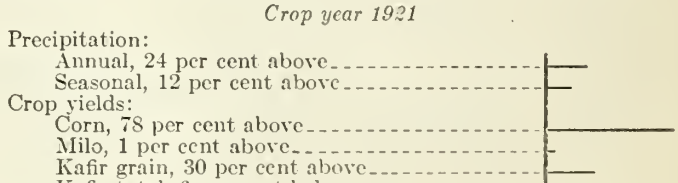
The crop year was the wettest in the history of the station. The precipitation was well distributed and sufficient to maintain crops in good condition at all times. All crops, including both winter and spring small grains, made good yields. Frost-free period, 192 days.

Crop year 1920



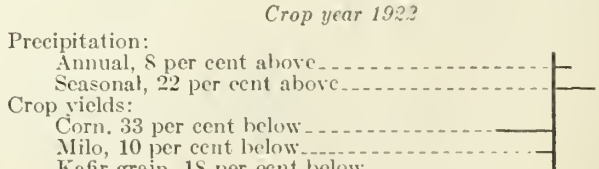
The distribution of precipitation was quite favorable to the production of adapted crops. Small grains have practically disappeared from the picture. The season was late on account of dryness until the rains began in May. The precipitation in June was the highest on record at this station, and in July and August it was sufficient to keep the crops growing well enough to mature and yield above the average. Frost-free period, 178 days.

Crop year 1921



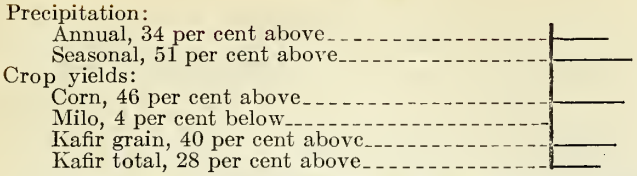
Precipitation was heavy in May, June, and July. All crops were in excellent condition from the time they emerged until after the middle of August. There was practically no rain in August and September, and crops began to suffer. Early plantings and early crops suffered little, but later plantings suffered more and ripened prematurely. Frost-free period, 178 days.

Crop year 1922



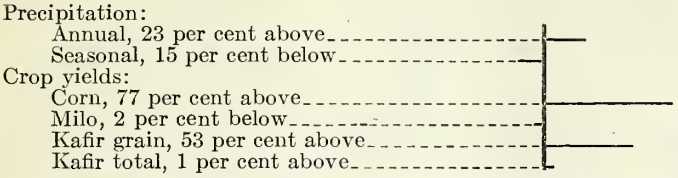
The greater part of the seasonal precipitation fell in the first part of the season, and crops were suffering from drought before the end of July. The weather continued hot and dry with only small local showers which were not sufficient to relieve the situation. Some plats made good yields, and others were nearly failures. Winter rye and oats yielded well. Frost-free period, 195 days.

Crop year 1923



Crop growth and development was checked by dry weather in July and the first half of August. Excessive rains began on August 1 and continued until after harvest. The crops started a new growth, but maturity was much delayed by the wet cool weather. Frost was late, but even then some crops did not mature properly. Wet weather interfered with harvesting and saved the crops. Rye and oats were failures. Frost-free period, 188 days.

Crop year 1924



The usual effects of a low seasonal precipitation were largely overcome by the water stored in the soil from the excessive rains of the preceding fall. Rye and oats were very poor and were damaged by rabbits. Before heavy rains came, about the middle of August, cultivated crops suffered from the deficient precipitation. Frost-free period, 188 days.

RESULTS AT TUCUMCARI, N. MEX.

[Altitude, 4,185 feet; 12-year period (figs. 40 and 41)]

Climatic conditions: Mean annual precipitation, 18.71 inches; mean seasonal precipitation, 13.97 inches; mean seasonal evaporation, 54.635 inches.

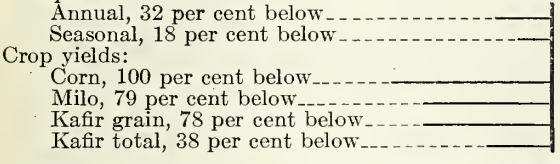
Average frost-free period, 191 days.

Soil: Sandy "yucca land."

Number of crop yields averaged each year: Corn, 7; milo, 25; kafir grain, 11; kafir total, 11.

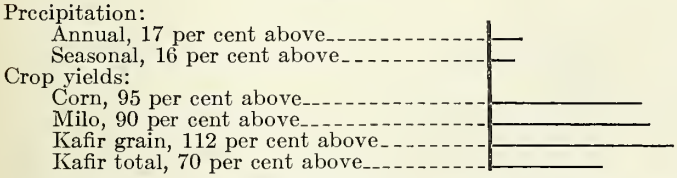
Average annual crop yields per acre: Corn, 16.6 bushels; milo, 25.7 bushels; kafir grain, 18.7 bushels; kafir total, 3,668 pounds.

Crop year 1913



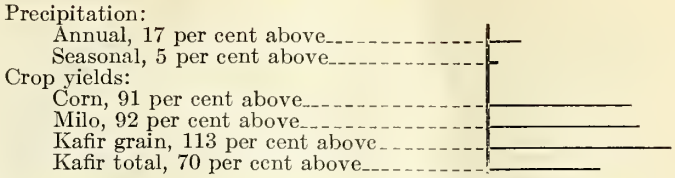
The soil was dry before the April rains, which wet it to a depth of about 3 feet. Hail on June 12 did some damage to the young crops, especially to cotton and cowpeas. It was necessary to replant the latter. The month of July was the most unfavorable of the season. Temperatures and wind movement were high, and evaporation was excessive. Small grains were destroyed by the dry weather and jack rabbits, the sorghum crops were damaged some by plant lice, and the yields of the sorghums were reduced to some extent by the attacks of birds. Frost-free period, 184 days.

Crop year 1914



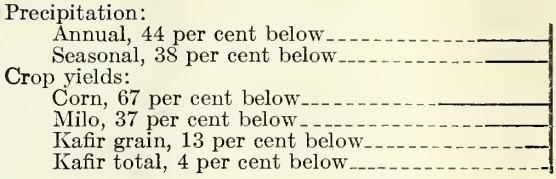
The season opened with the soil well filled with water, the rainfall was sufficient, and all crops grew steadily and rapidly throughout the growing season. There was no apparent lack of water until after most of the crops were matured. Frost-free period, 188 days.

Crop year 1915



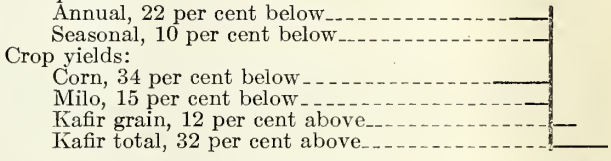
A shortage of rainfall in May, June, and the first two weeks of July affected small grains adversely. The rainfall from the middle of July to the end of the season was sufficient, and unusually good crops of the sorghums and corn were produced. A hailstorm on August 15 damaged cowpeas so they were attaeked by disease and were necessarily harvested early. The hail stripped the leaves of corn and the sorghums, but did not seem to reduce their yields. Frost-free period, 188 days.

Crop year 1916



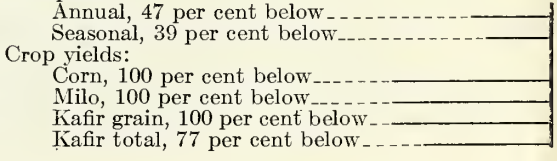
August was the only month with adequate precipitation. Soil blowing and planting in dry soil caused poor stands and in some cases necessitated replanting. Late crops made some fair yields, particularly of forage. The yields of the grain sorghums were reduced by birds. Frost-free period, 194 days.

Crop year 1917



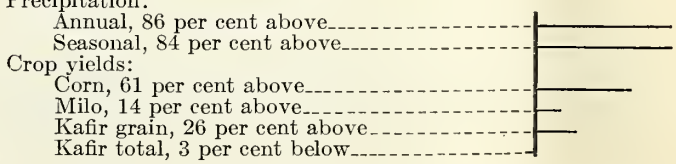
The dry fall, winter, and spring caused much soil blowing. Small grains failed. Cultivated crops started but made little growth until the drought was effectually broken by the rains in August. The first frost did not come until October 18, by which time all crops were either mature or burning badly. Frost-free period, 174 days.

Crop year 1918



Crops could not be planted until July, and the first rain sufficient to promote crop growth came on September 4. As a result of these severe conditions all crop yields were light and in most cases not worth harvesting. Frost-free period, 189 days.

Crop year 1919



In the spring there were delays from wet weather and damage from soil washing, and in the fall there was delay in harvesting and damage to the crops from excessive rainfall. Yields were uniformly good but not record breaking. Frost-free period, 203 days.

TUCUMCARI (N. MEX.) FIELD STATION

YEAR	INCHES	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL YEAR	CROP YIELDS		CROP YEAR
1912	4	0.10		0.13	0.28	0.51	0.16	4.51	1.11	2.80	0.42	1.71	0.94	12.67	CORN	0.0	1913
	3														MILO	5.5	
	2														KAFIR GRAIN	4.1	
	1														KAFIR TOTAL	2273.0	
1913	4	0.51	1.49	2.51	0.30	0.40	0.50	2.52	5.24	2.81	3.90	1.06	0.72	21.96	CORN	32.4	1914
	3														MILO	48.8	
	2														KAFIR GRAIN	39.6	
	1														KAFIR TOTAL	6219.0	
1914	4	3.48	T.	1.31	0.66	0.98	0.90	4.00	1.59	0.71	3.13	2.28	2.94	21.98	CORN	31.7	1915
	3														MILO	49.3	
	2														KAFIR GRAIN	39.8	
	1		T.												KAFIR TOTAL	6224.0	
1915	4	0.67	T.	0.27	0.70		0.09	1.55	0.56	0.63	0.56	4.43	0.56	10.44	CORN	5.5	1916
	3														MILO	16.1	
	2														KAFIR GRAIN	16.2	
	1		T												KAFIR TOTAL	3529.0	
1916	4	0.78	0.29	0.32	0.31	0.11	0.12	0.32	1.82	0.90	0.74	6.11	2.74	14.56	CORN	11.0	1917
	3														MILO	21.9	
	2														KAFIR GRAIN	21.0	
	1														KAFIR TOTAL	4831.0	
1917	4	0.16	0.62	0.04	0.10	0.13	0.21	1.14	0.21	0.70	2.54	1.02	2.85	9.82	CORN	0.0	1918
	3														MILO	0.0	
	2														KAFIR GRAIN	0.0	
	1														KAFIR TOTAL	825.0	
1918	4	2.60	0.51	2.00	0.04	0.32	3.69	3.91	5.84	6.39	4.16	2.54	4.16	34.85	CORN	26.7	1919
	3														MILO	29.2	
	2														KAFIR GRAIN	23.6	
	1														KAFIR TOTAL	3558.0	
1919	4	2.31	0.51	0.93	0.76	0.15	0.34	0.20	2.55	3.91	1.52	1.48	1.44	16.10	CORN	23.3	1920
	3														MILO	37.4	
	2														KAFIR GRAIN	20.2	
	1														KAFIR TOTAL	3302	
1920	4	3.68	0.49		1.56	0.32	0.83		8.72	5.88	3.65	1.86	0.75	27.74	CORN	26.0	1921
	3														MILO	44.7	
	2														KAFIR GRAIN	22.4	
	1														KAFIR TOTAL	4358.0	
1921	4	0.21		T.	0.13	0.13	1.37	2.64	2.04	1.24	1.65	0.67	1.86	11.28	CORN	3.3	1922
	3														MILO	10.9	
	2														KAFIR GRAIN	5.1	
	1			T											KAFIR TOTAL	1991.0	
1922	4	0.37	0.93			0.96	1.04	3.35	1.37	3.55	0.63	5.64	1.86	20.17	CORN	17.0	1923
	3														MILO	20.6	
	2														KAFIR GRAIN	14.6	
	1														KAFIR TOTAL	3090.0	
1923	4	7.51	1.69	1.64		0.19	0.60	0.63	1.67	2.07	1.93	3.79	1.31	23.03	CORN	22.2	1924
	3														MILO	24.2	
	2														KAFIR GRAIN	17.8	
	1														KAFIR TOTAL	3714.0	
AVERAGE		1.87	0.54	0.76	0.40	0.35	0.82	2.04	2.77	2.64	2.02	2.72	1.78	18.71			
MONTH		OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL YEAR			

FIG. 40.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Tucumcari (N. Mex.) Field Station

Crop year 1920

Precipitation:
- Annual, 14 per cent below
- Seasonal, 21 per cent below

Crop yields:
- Corn, 40 per cent above
- Milo, 46 per cent above
- Kafir grain, 8 per cent above
- Kafir total, 10 per cent below

From May until July there was plenty of moisture for planting and getting the crops well started. There were dry spells during the summer, but small showers which occurred from time to time kept the crops progressing slowly. Frost-free period, 188 days.

Crop year 1921

Precipitation:
- Annual, 48 per cent above
- Seasonal, 49 per cent above

Crop yields:
- Corn, 57 per cent above
- Milo, 74 per cent above
- Kafir grain, 20 per cent above
- Kafir total, 19 per cent above

Rains did not begin in the spring until May 13, and there were no effective rains after August 15. In spite of the lack of late rains the crops filled very well and yields were much above the average. Frost-free period, 197 days.

Crop year 1922

Precipitation:
- Annual, 40 per cent below
- Seasonal, 33 per cent below

Crop yields:
- Corn, 80 per cent below
- Milo, 58 per cent below
- Kafir grain, 73 per cent below
- Kafir total, 46 per cent below

At planting time, the middle to the latter part of May, there was sufficient water in the soil to insure good germination. By the latter part of June many of the plats were suffering from lack of water. This condition became more pronounced as the season advanced, and the yields on all plats were greatly reduced by it. Corn suffered from a borer (*Diatraea lineolata*), the corn earworm, and the cutworm, as well as from drought. Frost-free period, 187 days.

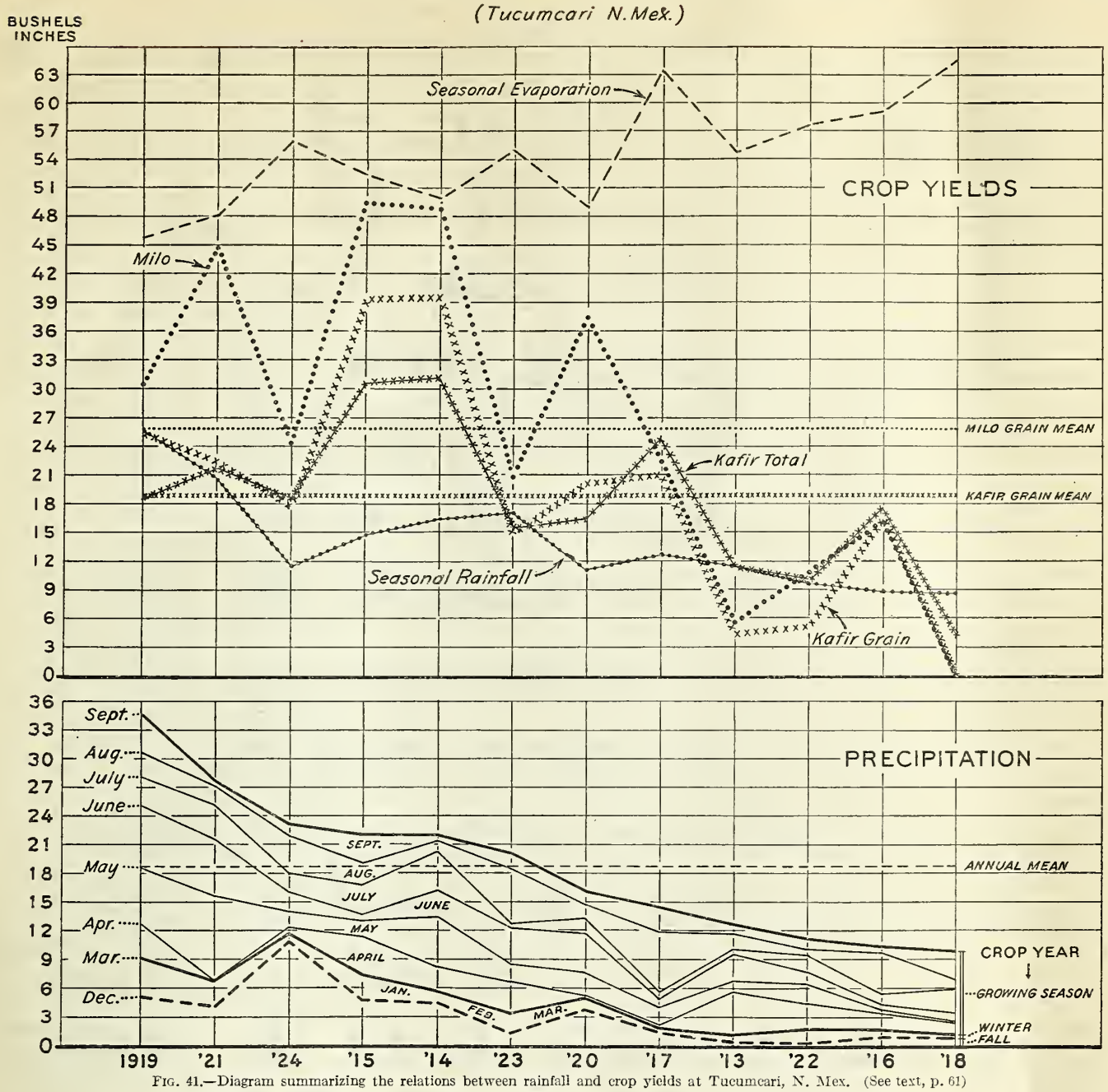


FIG. 41.—Diagram summarizing the relations between rainfall and crop yields at Tucumcari, N. Mex. (See text, p. 61)

Crop year 1923

Precipitation:
- Annual, 8 per cent above
- Seasonal, 21 per cent above

Crop yields:
- Corn, 2 per cent above
- Milo, 20 per cent below
- Kafir grain, 22 per cent below
- Kafir total, 16 per cent below

A severe drought during July and early August injured all crops materially, and excessive rains throughout the fall delayed maturity on many plats and resulted in much immature seed. Corn suffered a severe attack by borers, but made about the average yield. Frost-free period, 209 days.

Crop year 1924

Precipitation:
- Annual, 23 per cent above
- Seasonal, 18 per cent below

Crop yields:
- Corn, 34 per cent above
- Milo, 6 per cent below
- Kafir grain, 5 per cent below
- Kafir total, 1 per cent above

Planting was later than usual, because the surface soil was dry during the spring. On many plats full stands did not emerge until about July 1. Growth after that time was continuous and normally rapid, but full maturity was not reached on all plats. Corn was heavily infested with borers, but the damage from it was not as great as in the two previous years. Frost-free period, 196 days.

AMARILLO (TEX.) FIELD STATION

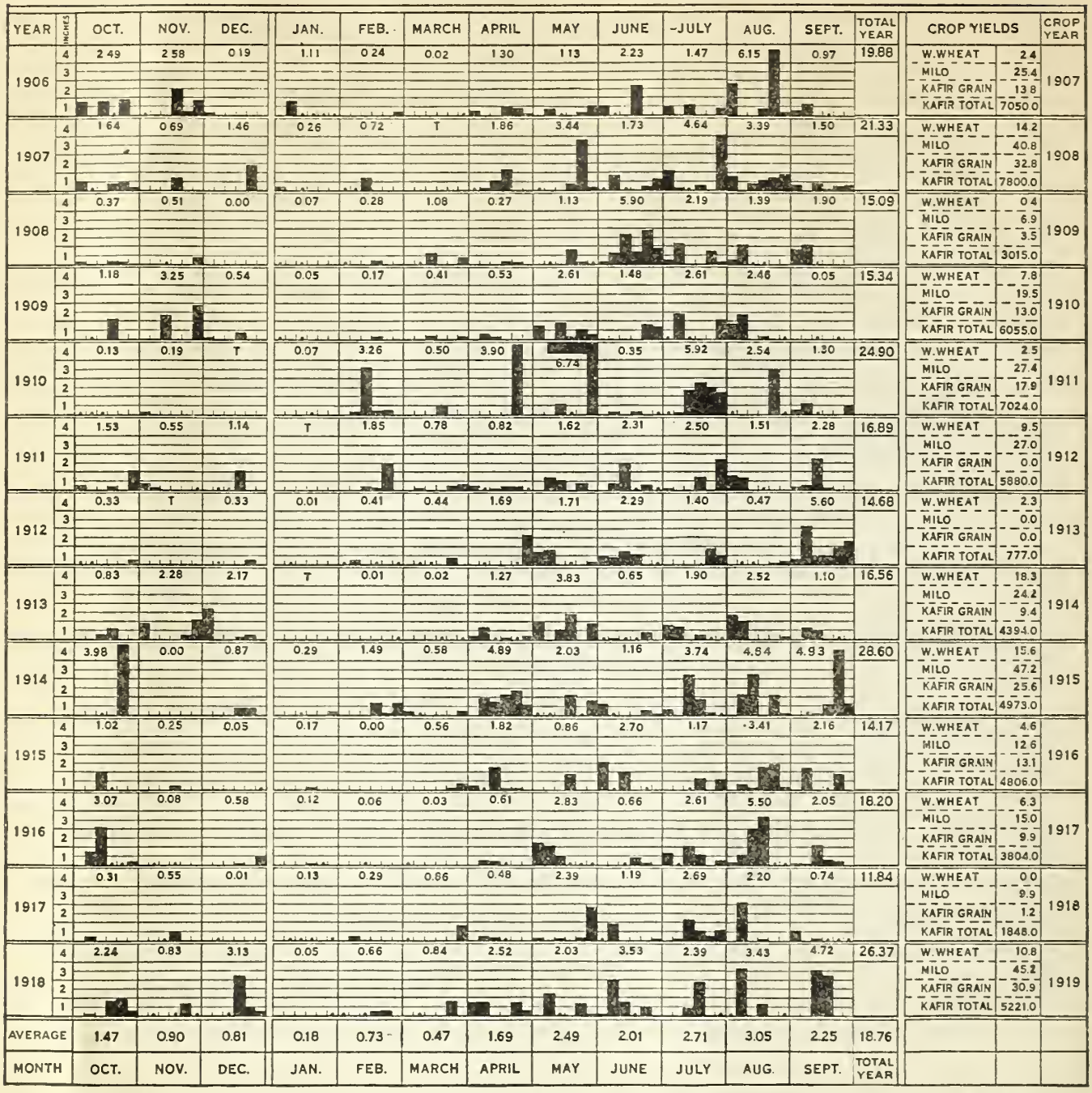


FIG. 42.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Amarillo (Tex.) Field Station

RESULTS AT AMARILLO, TEX.

[Altitude, 3,676 feet; 13-year period (figs. 42 and 43)]

Climatic conditions: Mean annual precipitation, 18.76 inches; mean seasonal precipitation, 14.20 inches; mean seasonal evaporation, 52.082 inches.

Average frost-free period, 189 days.

Soil: Heavy clay.

Number of crop yields averaged each year: Winter wheat, 15; milo, 12; kafir grain, 10; kafir total, 10.

Average annual crop yields per acre: Winter wheat, 7.3 bushels; milo, 23.2 bushels; kafir grain, 13.2 bushels; kafir total, 4,819 pounds.

Crop year 1907

Precipitation:
- Annual, 6 per cent above
- Seasonal, 7 per cent below

Crop yields:
- Winter wheat, 67 per cent below
- Milo, 9 per cent above
- Kafir grain, 5 per cent above
- Kafir total, 46 per cent above

Small grains were nearly destroyed by hail. Cultivated crops made about average yields. Frost-free period, 187 days.

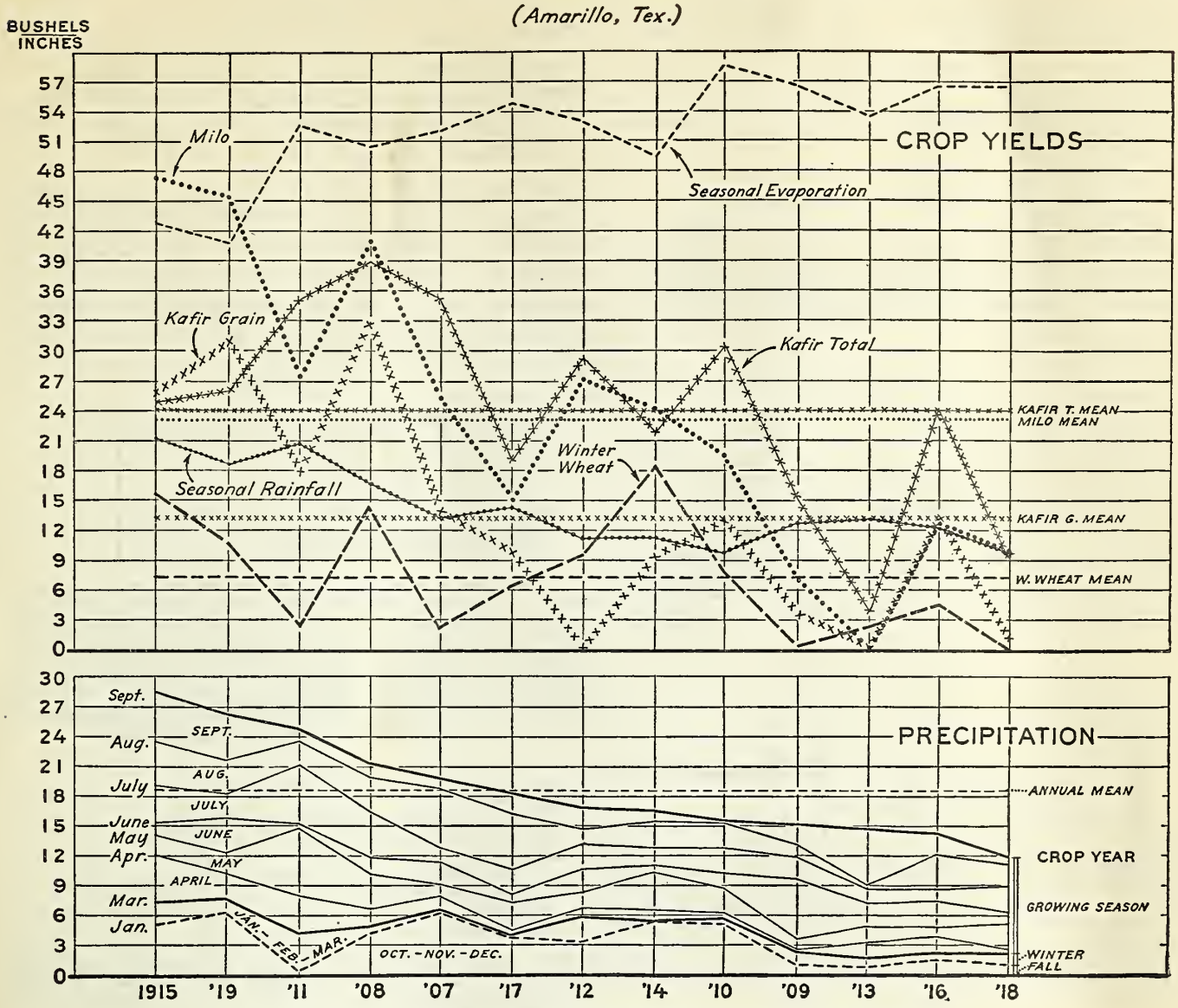


FIG. 43.—Diagram summarizing the relations between rainfall and crop yields at Amarillo, Tex.

Crop year 1908

Precipitation:
- Annual, 14 per cent above
- Seasonal, 17 per cent above

Crop yields:
- Winter wheat, 96 per cent above
- Milo, 76 per cent above
- Kafir grain, 149 per cent above
- Kafir total, 62 per cent above

One of the three best years in the history of the station. Frost-free period, 192 days.

Crop year 1909

Precipitation.
- Annual, 20 per cent below
- Seasonal, 10 per cent below

Crop yields:
- Winter wheat, 95 per cent below
- Milo, 70 per cent below
- Kafir grain, 73 per cent below
- Kafir total, 37 per cent below

The fall, winter, and spring was a period of continued drought which was not broken by heavy rains until about the middle of June. The only small grains that survived and produced anything were those on fallow. The latter part of the summer was too dry for the development of corn and the sorghums under general and ordinary methods of cultivation, but milo on summer fallow gave about average yields. Frost-free period, 196 days.

Crop year 1910

Precipitation:
- Annual, 18 per cent below
- Seasonal, 31 per cent below

Crop yields:
- Winter wheat, 7 per cent above
- Milo, 16 per cent below
- Kafir grain, 2 per cent below
- Kafir total, 26 per cent above

Winter wheat came through the winter in fair condition, but suffered from drought except for a time in May. Spring grains germinated very unevenly, some coming up shortly after seeding in March and some not until after the rain in May. The sorghums suffered from drought in the latter part of the season. Frost-free period, 197 days.

Crop year 1911

Precipitation:
- Annual, 33 per cent above
- Seasonal, 46 per cent above

Crop yields:
- Winter wheat, 66 per cent below
- Milo, 18 per cent above
- Kafir grain, 36 per cent above
- Kafir total, 46 per cent above

Precipitation was high and yields of all crops except winter wheat were good, but not in full proportion to the precipitation,

which was not well distributed. Winter wheat did not come up in the fall and did poorly in the spring. Frost-free period, 209 days.

Crop year 1912

Precipitation:
- Annual, 10 per cent below
- Seasonal, 22 per cent below

Crop yields:
- Winter wheat, 27 per cent above
- Milo, 16 per cent above
- Kafir grain, 100 per cent below
- Kafir total, 22 per cent above

Precipitation for both the season and the crop year was below the normal, but it was very well distributed. The season was described as dry throughout, but no other factors interfered with production. No stand of kafir was secured from the first planting, and the second planting was too late to mature. Frost-free period, 153 days.

Crop year 1913

Precipitation:
- Annual, 22 per cent below
- Seasonal, 7 per cent below

Crop yields:
- Winter wheat, 68 per cent below
- Milo, 100 per cent below
- Kafir grain, 100 per cent below
- Kafir total, 84 per cent below

The precipitation for the crop year was only 14.60 inches, and 5.60 inches of this came in September, after crops had succumbed to the drought. Milo on fallow produced a little grain, but it was eaten by birds. A little winter wheat was harvested. Frost-free period, 185 days.

Crop year 1914

Precipitation:
- Annual, 12 per cent below
- Seasonal, 21 per cent below

Crop yields:
- Winter wheat, 150 per cent above
- Milo, 4 per cent above
- Kafir grain, 29 per cent below
- Kafir total, 9 per cent below

Crops were benefited by the water stored in the soil from the September, 1913, rains. Small grains made a good growth of straw, but the yields were reduced by the hot, dry weather in June. In spite of this the yield of winter wheat was the best in the history of the station. Corn did not ear. Milo and kafir suffered intermittently from drought and matured in the latter part of August which was much earlier than usual. Kafir especially suffered from a lack of water when the grain should have been filling. Frost-free period, 191 days.

Crop year 1915

Precipitation:
- Annual, 52 per cent above
- Seasonal, 50 per cent above

Crop yields:
- Winter wheat, 114 per cent above
- Milo, 103 per cent above
- Kafir grain, 94 per cent above
- Kafir total, 3 per cent above

The chief adverse conditions interrupting the generally favorable weather conditions were a late frost in May and a period of drought in June. The frost chiefly affected winter wheat and oats, and the dry, hot weather in June reduced the yields of all small grains. Frost-free period, 191 days.

Crop year 1916

Precipitation:
- Annual, 24 per cent below
- Seasonal, 15 per cent below

Crop yields:
- Winter wheat, 37 per cent below
- Milo, 46 per cent below
- Kafir grain, 1 per cent below
- Kafir total, mean.

The grain sorghums made little headway until the rains beginning August 19, which were in time to benefit them greatly. Frost-free period, 193 days.

Crop year 1917

Precipitation:
- Annual, 3 per cent below
- Seasonal, mean.

Crop yields:
- Winter wheat, 14 per cent below
- Milo, 35 per cent below
- Kafir grain, 25 per cent below
- Kafir total, 21 per cent below

Very little water was carried over in the soil, and only three or four rainy periods yielded precipitation sufficient to help crops. Only one of these, the rainy spell of the second week of May, was in time to help small grains. The drought in the latter half of May and all of June resulted in a practical failure of all the small grains. Corn and milo were suffering desperately before relief came in the August rains. They recovered to some extent, and the grain sorghums started a second growth, but this did not fully mature before frost. Frost-free period, 166 days.

Crop year 1918

Precipitation:
- Annual, 37 per cent below
- Seasonal, 32 per cent below

Crop yields:
- Winter wheat, 100 per cent below
- Milo, 57 per cent below
- Kafir grain, 91 per cent below
- Kafir total, 62 per cent below

The fall and winter were so dry that winter wheat did not survive. Beginning the latter part of May, moisture conditions became more favorable, but owing to the lack of stored water in the soil a shortage existed throughout the season. The showers were as a rule too light to give crops more than temporary relief. Small grains failed almost completely. Corn failed to make any grain, and kafir was delayed until only a part of it matured. Milo made some grain on all plats and a good yield on some fallow plats. Frost-free period, 189 days.

Crop year 1919

Precipitation:
- Annual, 41 per cent above
- Seasonal, 31 per cent above

Crop yields:
- Winter wheat, 48 per cent above
- Milo, 95 per cent above
- Kafir grain, 134 per cent above
- Kafir total, 8 per cent above

The yield of winter wheat and other small grains was reduced somewhat by hail and that of winter wheat possibly by rust. Corn made its usual poor yield of low quality. Milo and kafir developed normally. Frost-free period, 207 days.

RESULTS AT LAWTON, OKLA.

[Altitude, 1,200 feet; 9-year period (figs. 44 and 45)]

Climatic conditions: Mean annual precipitation, 28.51 inches; mean seasonal precipitation, 17.45 inches; mean seasonal evaporation, 43.308 inches.

Average frost-free period, 214 days.

Soil: Heavy clay.

Number of crops averaged each year: Winter wheat, 26; lint cotton, 27; kafir grain, 33; kafir total, 33.

Average annual crop yields per acre: Winter wheat, 16.6 bushels; lint cotton, 200 pounds; kafir grain, 16 bushels; kafir total, 4,002 pounds.

Crop year 1916

Precipitation:
- Annual, 28 per cent below
- Seasonal, 8 per cent below

Crop yields:
- Winter wheat, 50 per cent below
- Lint cotton, 42 per cent below
- Kafir grain, 80 per cent below
- Kafir total, 41 per cent below

Small grains were injured by dry, windy weather in March and were ripened prematurely by dry weather in May and June. The yields were also reduced by chinch bugs. Corn was

destroyed by chinch bugs. Sorghums suffered from drought in the latter part of July and August, but probably would have made fairly satisfactory yields if it had not been for chinch bugs, which destroyed some and badly injured others. During the severe conditions of summer there was a heavy abortion of cotton squares, and only a top crop was produced. Frost-free period, 194 days.

Crop year 1917

Precipitation:
- Annual, 34 per cent below
- Seasonal, 23 per cent below

Crop yields:
- Winter wheat, 14 per cent below
- Lint cotton, 17 per cent above
- Kafir grain, 14 per cent below
- Kafir total, 23 per cent above

Lack of water in the spring made it difficult to secure stands and much late replanting was necessary. Heavy rain on May 30 enabled wheat to ripen normally. All chance for a corn crop was destroyed by hot winds in the latter part of June and the first of July. Other crops, including the first crop of kafir heads, were badly injured at the same time. The first crop of kafir heads were badly blasted and the greater part of the yield was from later branch heads. Cotton stood the hot weather better than other crops and suffered more from drought in the cool weather of September than at any other time. Milo and corn suffered more than other crops from chinch bugs. Frost-free period, 189 days.

Crop year 1918

Precipitation:
- Annual, 34 per cent below
- Seasonal, 14 per cent below

Crop yields:
- Winter wheat, 83 per cent below
- Lint cotton, 100 per cent below
- Kafir grain, 100 per cent below
- Kafir total, 65 per cent below

Wheat was too severely damaged by drought and chinch bugs to benefit from the 2.34 inches of rainfall in the first week of June. Corn was planted April 9 and did very well until the third week in June, when it soon yielded to hot parching winds without forming many tassels. Some plats received much injury from chinch bugs. All oat plats were heavily infested with chinch bugs, which only hastened the effect of the drought and hot winds. Hot winds and drought retarded the growth of cotton and aborted squares as rapidly as they formed. Bolls formed in September and October, too late in the season to develop. Kafir, planted on May 6, made about normal growth until the middle of June, when it was injured by hot winds and chinch bugs and barely kept alive during the remainder of the season. Most of it headed but did not make grain. Milo succumbed more quickly and completely than kafir. Frost-free period, 223 days.

Crop year 1919

Precipitation:
- Annual, 41 per cent above
- Seasonal, 25 per cent above

Crop yields:
- Winter wheat, 53 per cent above
- Lint cotton, 75 per cent above
- Kafir grain, 74 per cent above
- Kafir total, 39 per cent above

Precipitation was excessive, and the season was free from the high winds and soil blowing in spring, the hot winds of summer, and the attacks of chinch bugs. Winter wheat was damaged somewhat by army worms, which went to the corn as the wheat ripened and did some damage there. Cotton was late and its quality was injured by the excessive precipitation in October and continued wet weather in November. Frost-free period, 246 days.

Crop year 1920

Precipitation:
- Annual, 39 per cent above
- Seasonal, 11 per cent above

Crop yields:
- Winter wheat, 33 per cent above
- Lint cotton, 97 per cent above
- Kafir grain, 122 per cent above
- Kafir, total, 54 per cent above

The quality of forage and grain was good. June and July were dry, but the soil was well filled with water, and crops suffered but little from drought. Wheat was infested with chinch bugs, but its growth was so strong that they probably reduced its yield but little. They did some damage to corn and injured milo seriously. Frost-free period, 211 days.

Crop year 1921

Precipitation:
- Annual, 12 per cent above
- Seasonal, 12 per cent below

Crop yields:
- Winter wheat, 14 per cent below
- Lint cotton, 28 per cent below
- Kafir grain, 48 per cent above
- Kafir total, 18 per cent above

The season was favorable to crop growth until May, when small grains suffered for water. Row crops had not made much demand on soil moisture up to this time and were pushed along in good condition by abnormal rainfall in June and about normal precipitation in July. About the middle of July a severe drought began that continued throughout the season. Hot winds and high temperatures in August reduced the yields of row crops, which began to show serious effects of the drought about the 10th of the month. The mild winter was apparently responsible for an unusual number of insect pests which very noticeably damaged small grains, sorghums, and cotton. Green bugs damaged the winter wheat, chinch bugs damaged corn and the sorghums, and boll weevils seriously infested the cotton. Frost-free period, 207 days.

Crop year 1922

Precipitation:
- Annual, 19 per cent below
- Seasonal, 15 per cent above

Crop yields:
- Winter wheat, 83 per cent below
- Lint cotton, 30 per cent below
- Kafir grain, 87 per cent below
- Kafir total, 52 per cent below

Fall and winter drought left the ground seeded to winter wheat practically bare until the winter rains. The wheat was injured by leaf rust and chinch bugs and died in the dry weather of June. Corn and the sorghums were ravaged by chinch bugs throughout the summer and suffered from high temperatures, hot winds, and a shortage of water from June and thereafter. The growth of cotton was satisfactory until the middle of July. Lack of water after that time reduced the crop to a low yield, short staple, and weak lint. Frost-free period, 239 days.

Crop year 1923

Precipitation:
- Annual, 5 per cent above
- Seasonal, 13 per cent above

Crop yields:
- Winter wheat, 30 per cent above
- Lint cotton, 44 per cent below
- Kafir grain, 42 per cent below
- Kafir total, 33 per cent below

Winter wheat made a heavy growth of straw and matured early in June without suffering from a lack of water. Heat and drought, from the latter part of June to the last days of August, cut the production of corn to a minimum. Milo was destroyed entirely by chinch bugs. Hot winds, drought, and chinch bugs reduced kafir to a low yield of very poor quality. Cotton suffered from cold wet weather in the spring, webworms in June, drought and grasshoppers in the summer, and excessive precipitation in the fall. Frost-free period, 215 days.

Crop year 1924

Precipitation:
- Annual, 18 per cent above
- Seasonal, 6 per cent below

Crop yields:
- Winter wheat, 131 per cent above
- Lint cotton, 56 per cent above
- Kafir grain, 81 per cent above
- Kafir total, 57 per cent above

The only period of drought suffering was in the first 10 days of August. The season was very free of the insect enemies that

LAWTON (OKLA.) FIELD STATION

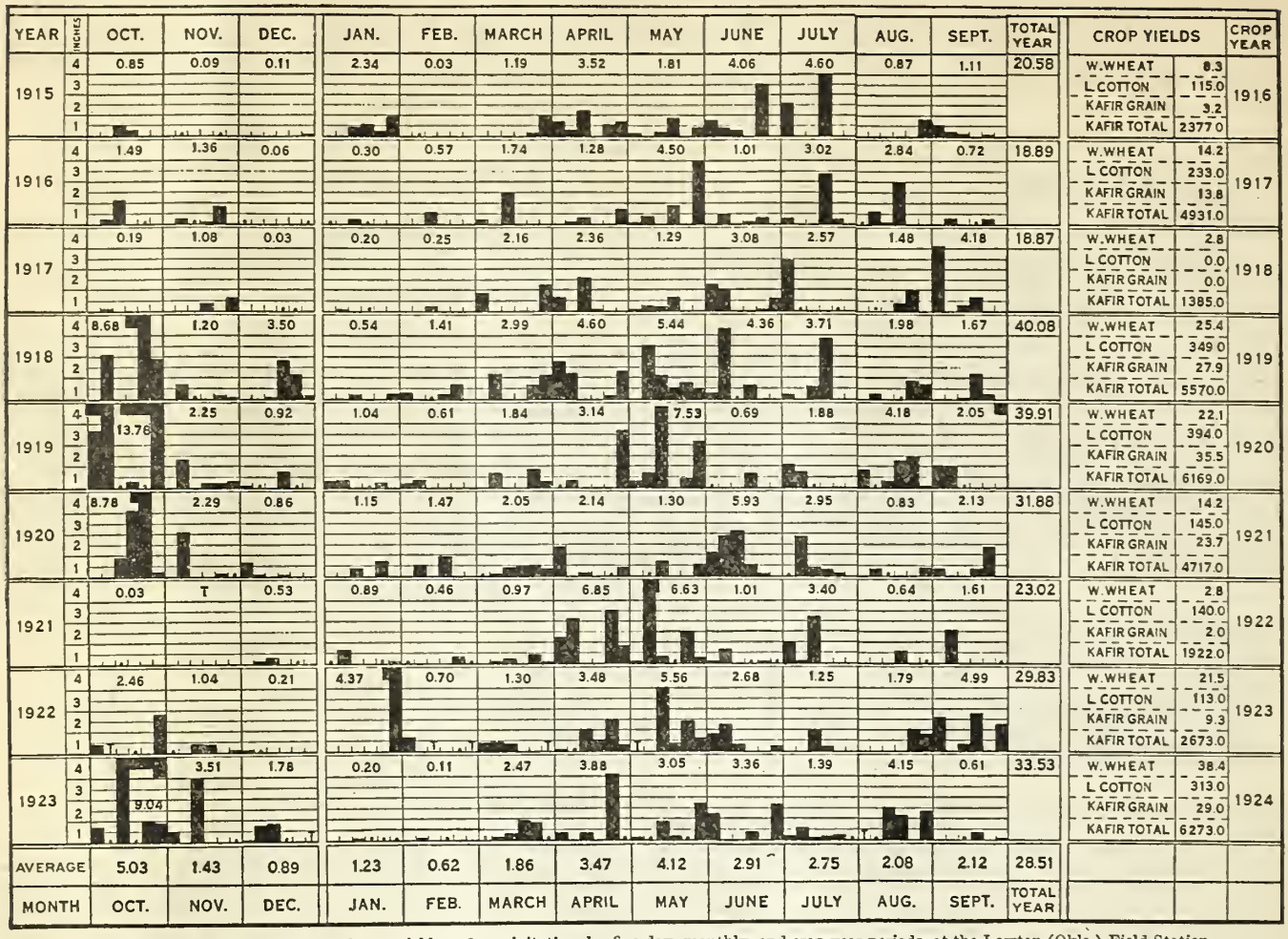


FIG. 44.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Lawton (Okla.) Field Station

characterized other years. Persistent efforts were necessary to control grasshoppers in the cotton plats. Frost-free period, 206 days.

RESULTS AT BIG SPRING, TEX.

[Altitude, 2,400 feet; 9-year period (figs. 46 and 47)]

Climatic conditions: Mean annual precipitation, 17.80 inches; mean seasonal precipitation, 12.06 inches; mean seasonal evaporation, 58.372 inches.

Average frost-free period, 212 days.

Soil: Sandy loam, high prairie.

Number of crop yields averaged each year: Milo, 38; kafir grain, 12; kafir total, 12; cotton, 20.

Average annual crop yields per acre: Milo, 22.2 bushels; kafir grain, 15.6 bushels; kafir total, 3,562 pounds; lint cotton, 206 pounds.

Crop year 1916

Precipitation:
- Annual, 14 per cent below
- Seasonal, 5 per cent below

Crop yields:
- Milo, 12 per cent above
- Kafir grain, 26 per cent above
- Kafir total, 72 per cent above
- Seed cotton, 64 per cent below

Winter wheat was cut short by drought, May was dry with high winds, and June and the first 27 days of July were dry and very hot. August was the most favorable month of the summer in regard to temperature and rainfall. Most crops not too badly burned by the drought revived and put on new growth. The sorghums were the crops that revived the most. Most varieties of cotton withstood the drought remarkably well, and if it had not been for an attack of the bollworm, good yields would have been obtained on all plats. Frost-free period, 195 days

Crop year 1917

Precipitation:
- Annual, 61 per cent below
- Seasonal, 65 per cent below

Crop yields:
- Milo, 63 per cent below
- Kafir grain, 94 per cent below
- Kafir total, 89 per cent below
- Seed cotton, 92 per cent below

The section represented by the Big Spring station was visited in 1917 by the severest drought recorded since climatic records have been kept. Practically the only production was light yields on fallow. Frost-free period, 165 days.

Crop year 1918

Precipitation:
- Annual, 53 per cent below
- Seasonal, 43 per cent below

Crop yields:
- Milo, 90 per cent below
- Kafir grain, 100 per cent below
- Kafir total, 63 per cent below
- Seed cotton, 68 per cent below

The failures and low yields were the result of the second year of continued extreme drought. Planting was completed and stands obtained following the receipt of 3½ inches of rain in the first week of June. From this rainy period to the early part of September less than half an inch of rain fell. New growth, notably in kafir, after the September rains increased the yield of forage. Frost-free period, 223 days.

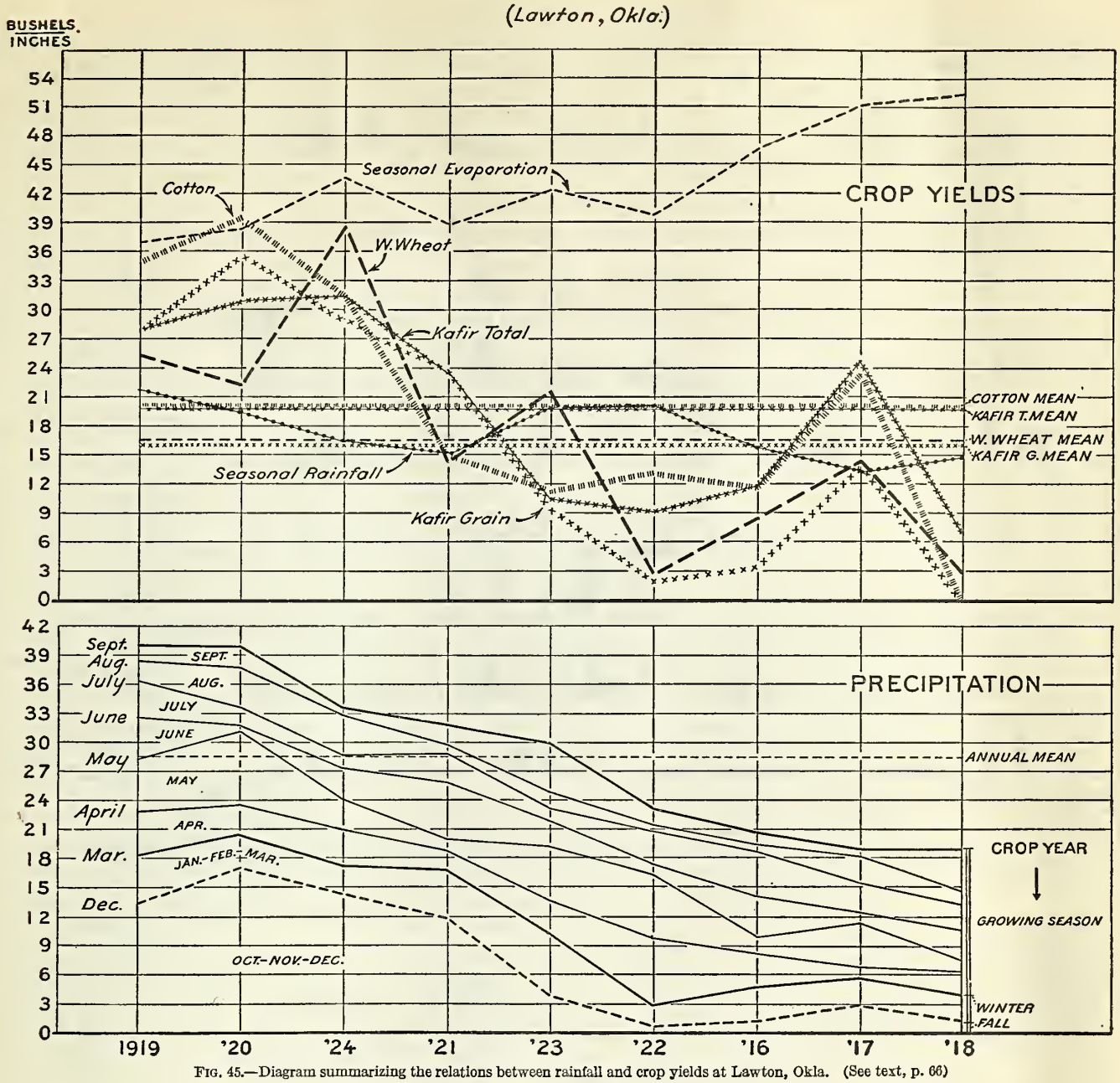


FIG. 45.—Diagram summarizing the relations between rainfall and crop yields at Lawton, Okla. (See text, p. 66)

Crop year 1919

Precipitation:
- Annual, 73 per cent above
- Seasonal, 91 per cent above

Crop yields:
- Milo, 126 per cent above
- Kafir grain, 114 per cent above
- Kafir total, 70 per cent above
- Seed cotton, 91 per cent above

Following two years of extreme drought the crop year was the wettest in the history of the station. The precipitation equaled that of the three preceding years combined. There was some washing and loss of stands in June. The low precipitation in July and the first three weeks of August caused the sorghum crops to ripen rapidly, and most of them were harvested by the middle of August. The excessive precipitation of September and October caused much spoilage and loss to crops still in the field. Frost-free period, 246 days.

Crop year 1920

Precipitation:
- Annual, 35 per cent above
- Seasonal, 21 per cent above

Crop yields:
- Milo, 35 per cent above
- Kafir grain, 81 per cent above
- Kafir total, 60 per cent above
- Seed cotton, 120 per cent above

Good rains in the fall and winter filled the subsoil with water, but the surface was dry in the spring, and planting was delayed until after the rains about the middle of May. Winter wheat was harvested June 9. Dry hot weather in July caused all crops to mature very rapidly. Most of the grain sorghums were matured before the August rains came. Late-planted and late-maturing crops were benefited by these rains and made larger yields. Conditions especially favored cotton, which is a late crop. Frost-free period, 213 days.

BIG SPRING (TEX.) FIELD STATION

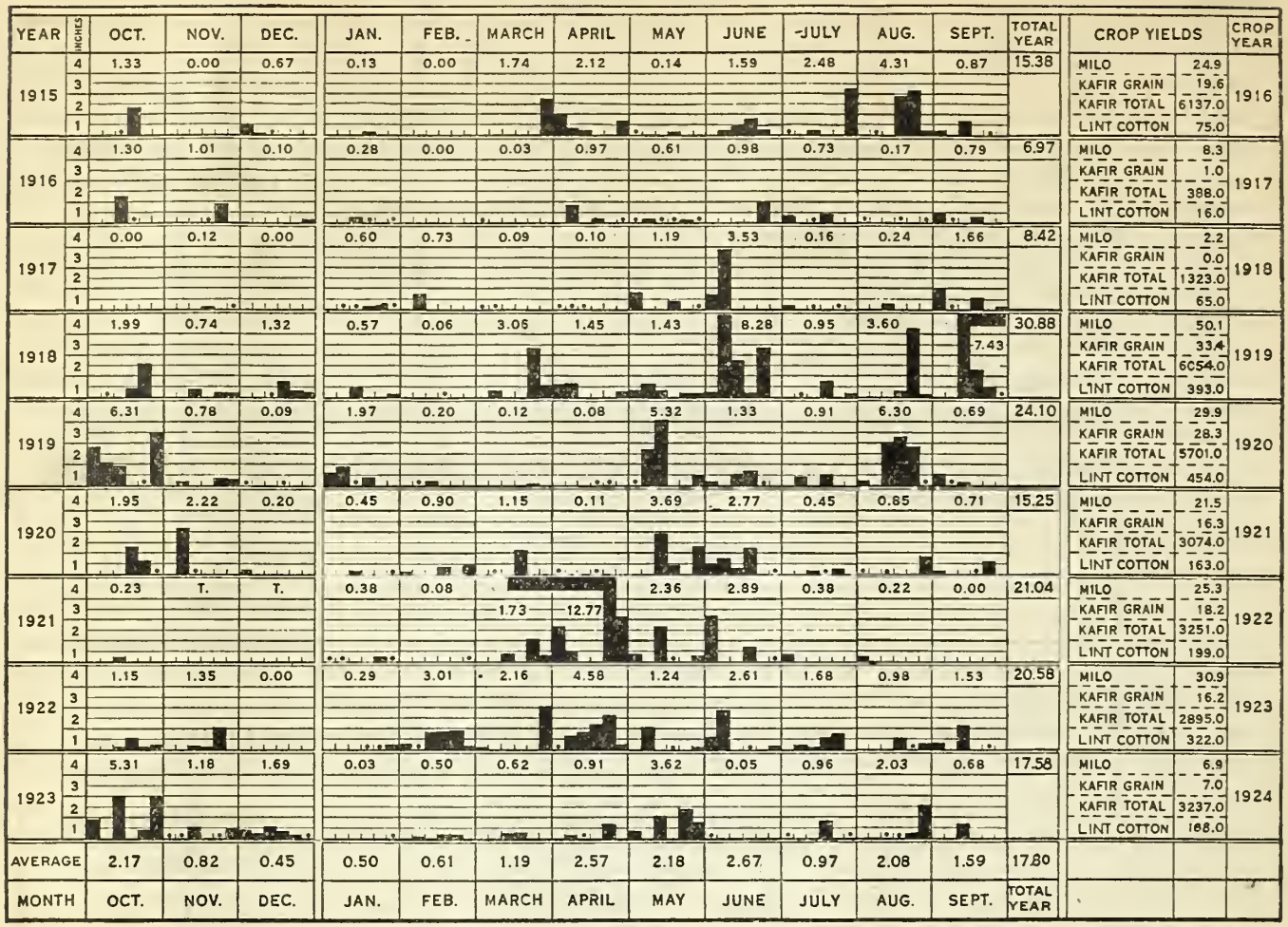


FIG. 46.—Relations between annual crop yields and precipitation, by five-day, monthly, and crop-year periods, at the Big Spring (Tex.) Field Station

Crop year 1921

Precipitation:
- Annual, 14 per cent below
- Seasonal, 29 per cent below

Crop yields:
- Milo, 3 per cent below
- Kafir grain, 4 per cent above
- Kafir total, 14 per cent below
- Seed cotton, 21 per cent below

Light precipitation in the spring of 1921 delayed the planting of the main crops until after the middle of May. The rainfall from May 14 to June 30 was ample to start the young crops into vigorous growth, but drought and high temperatures in July, August, and September reduced yields. Rain and hail on May 31 necessitated much replanting. Frost-free period, 174 days.

Crop year 1922

Precipitation:
- Annual, 18 per cent above
- Seasonal, 55 per cent above

Crop yields:
- Milo, 14 per cent above
- Kafir grain, 17 per cent above
- Kafir total, 9 per cent below
- Seed cotton, 3 per cent below

The soil was so dry in the fall and winter that no fall planting was done and but little tillage accomplished until late in March. The precipitation for the crop year and the season was above normal, but 12.77 inches came in April, more than 7.5 inches falling within 24 hours. There was considerable run-off. Cotton yielded very well, considering the fact that it received only 0.6 inch of rain after July 1. Kafir did not withstand the drought as well as milo. Frost-free period, 247 days.

Crop year 1923

Precipitation:
- Annual, 16 per cent above
- Seasonal, 5 per cent above

Crop yields:
- Milo, 39 per cent above
- Kafir grain, 4 per cent above
- Kafir total, 19 per cent below
- Seed cotton, 56 per cent above

The season as a whole was favorable to the production of the staple crops of the locality. The principal factor in determining yields was dry weather in July and August. Kafir plats were injured by birds. The quality of cotton and unthreshed grains was injured by the heavy rains beginning in October. Frost-free period, 214 days.

Crop year 1924

Precipitation:
- Annual, 1 per cent below
- Seasonal, 32 per cent below

Crop yields:
- Milo, 69 per cent below
- Kafir grain, 55 per cent below
- Kafir total, 9 per cent below
- Seed cotton, 18 per cent below

Cotton did relatively better than other crops, its yields being only 18 per cent below the 9-year average. The yields of other crops were very low. The controlling factor was the extremely hot and dry weather of June, July, and the first three weeks of August. Frost-free period, 232 days.

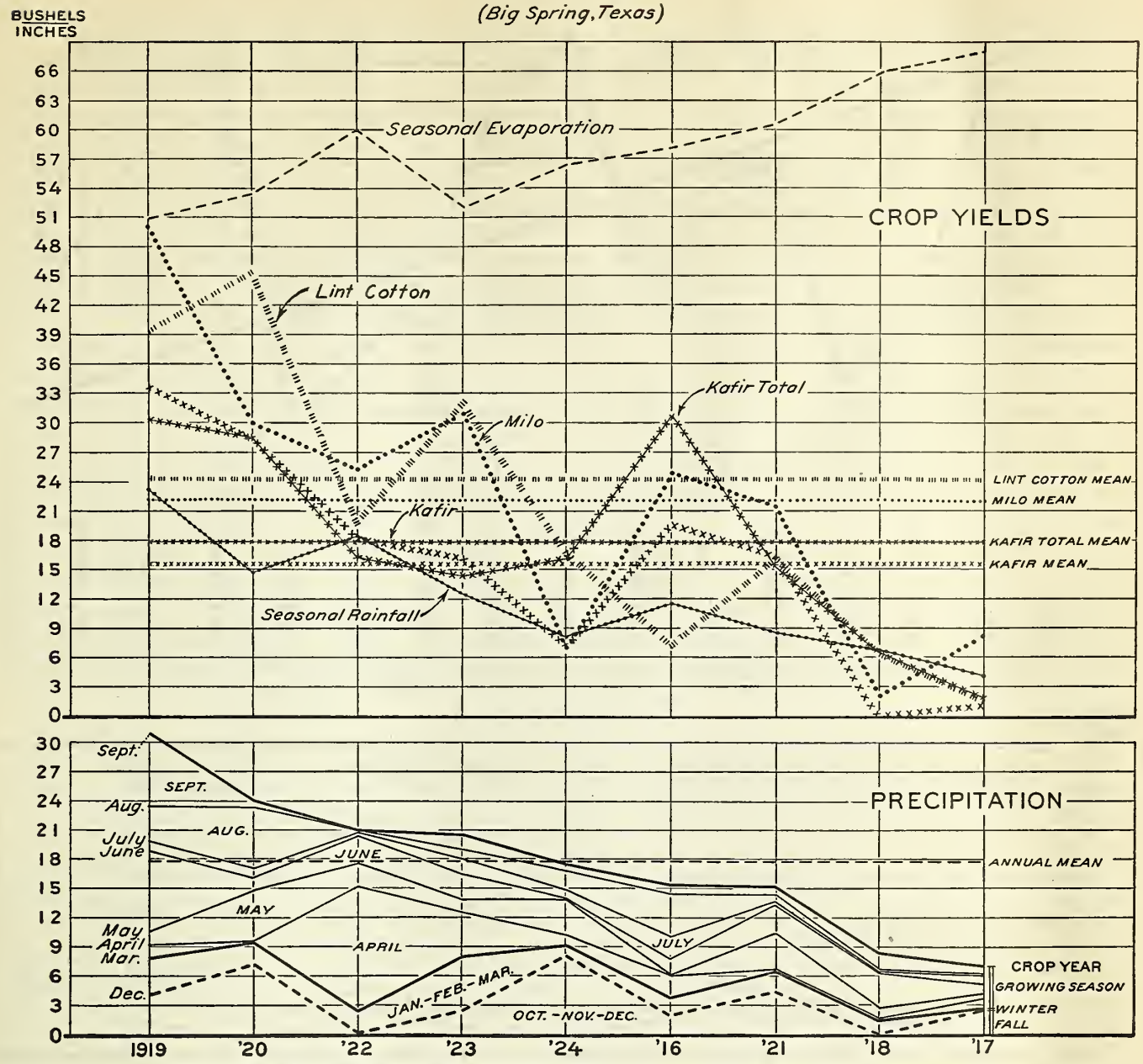


FIG. 47.—Diagram summarizing the relations between rainfall and crop yields at Big Spring, Tex. (See text, p. 68)

RESULTS AT THE NORTHERN GROUP OF 16 STATIONS

GROUPING OF COMPOSITE CROP YIELDS

In the preceding pages four staple crops have been used for comparison at each of the 23 stations located in the 10 States lying wholly or in part within the Great Plains area. Crop yields aggregating 28,400 in number have been grouped into 1,235 average annual yields per acre covering a period of time aggregating 303 years. Meteorological observations have been made each day for a total of 110,595 days. The precipitation for this period has been reported herein in five-day, monthly, seasonal, and annual periods. It was, of course, impossible to use the same four crops at all stations, as no four crops could be found that are equally adapted to all parts of a region extending from Canada to Mexico.

This wealth of detailed information provides a basis for many instructive and interesting studies and comparisons of crop with crop at the same station, or at other stations where the same crops were grown. But the crop yields recorded in Figures 2 to 47 are not sufficiently homogeneous to serve as a definite, quantitative basis for the study of the broad problem of the relations between crop yields and precipitation. It therefore was deemed desirable to regroup the data from 16 of the northern stations where winter wheat, spring wheat, and oats are staple crops, and to combine these three crops into a single composite unit equivalent to 1 bushel of wheat. This has been done by assuming that 2 bushels of oats are equivalent to 1 bushel of wheat. This assumption is fully warranted by the yields obtained from these three crops at the 16 stations, as shown in Table 3 (p. 4). The averages of these composite yields for each of the 16 stations are summarized in Table 5 (p. 73), and they are presented in detail for ready comparison in Table 7 (p. 75).

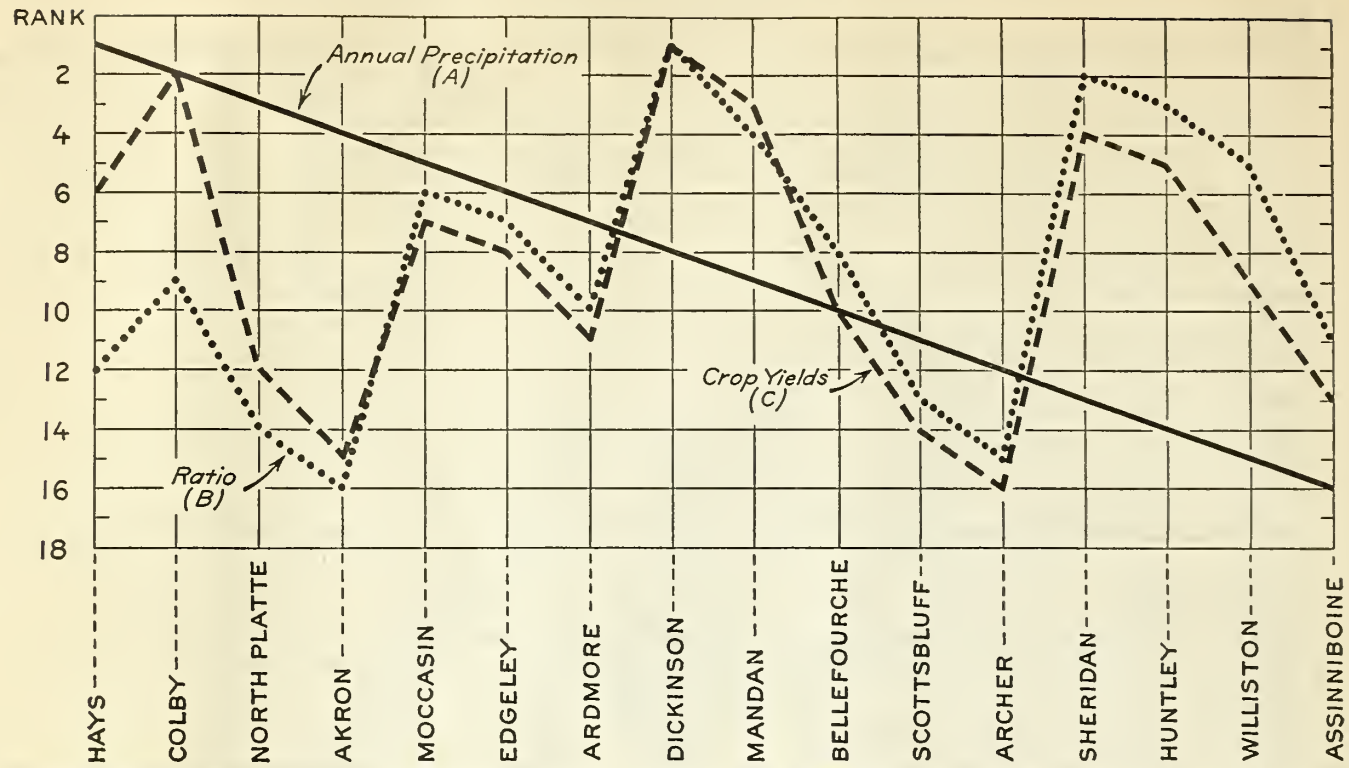


FIG. 48.—Diagram summarizing the relations between the ranks of each of 16 northern Great Plains field stations, based upon annual precipitation, ratios, and crop yields, as shown in columns A, B, and C in Table 7. (See text, p. 76)

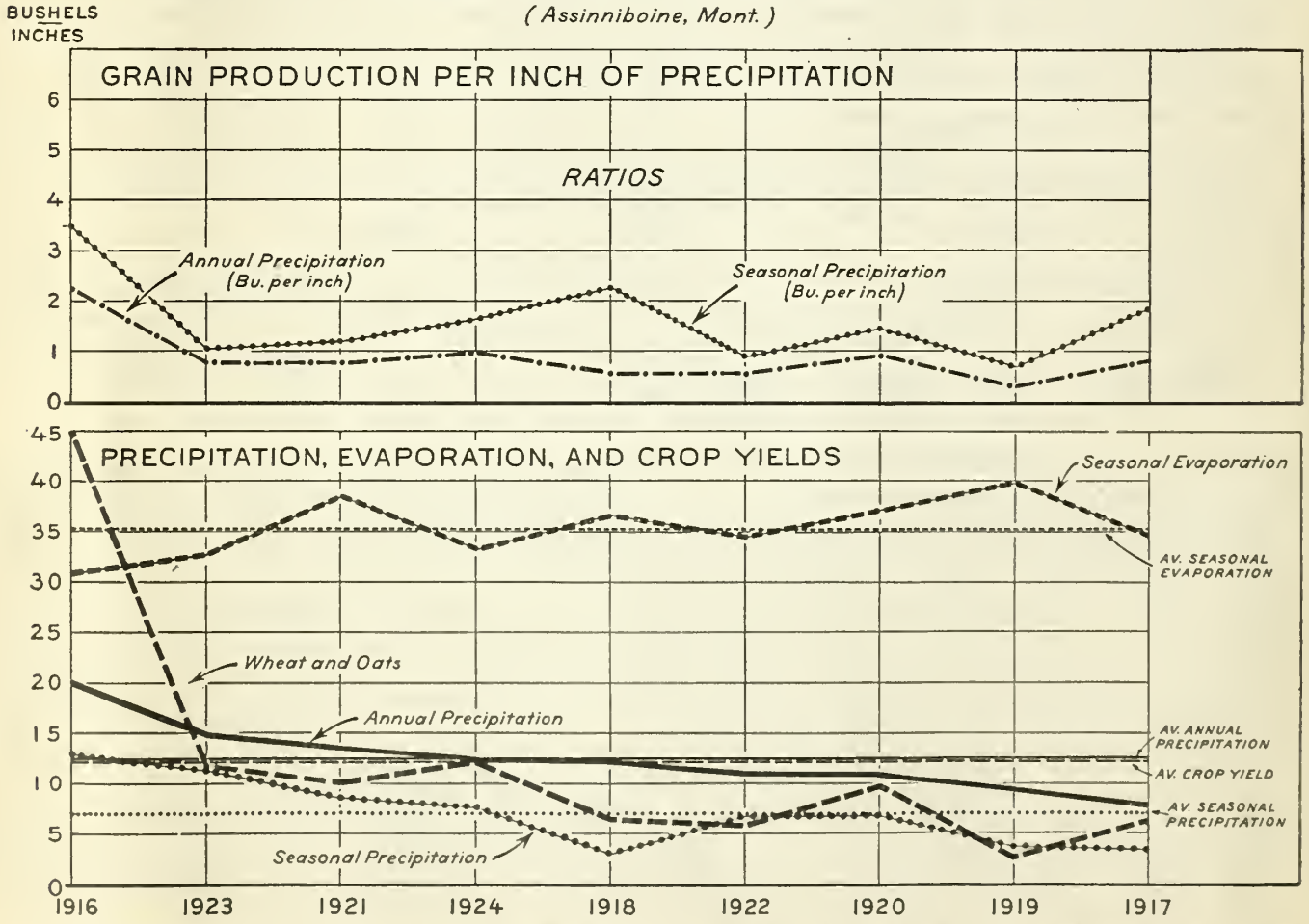


FIG. 49.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 32, sprin wheat 30, oats 58, total 120; for a period of nine years, at the Assiniboine (Mont.) Field Station. (See Tables 7, 13, and 14)

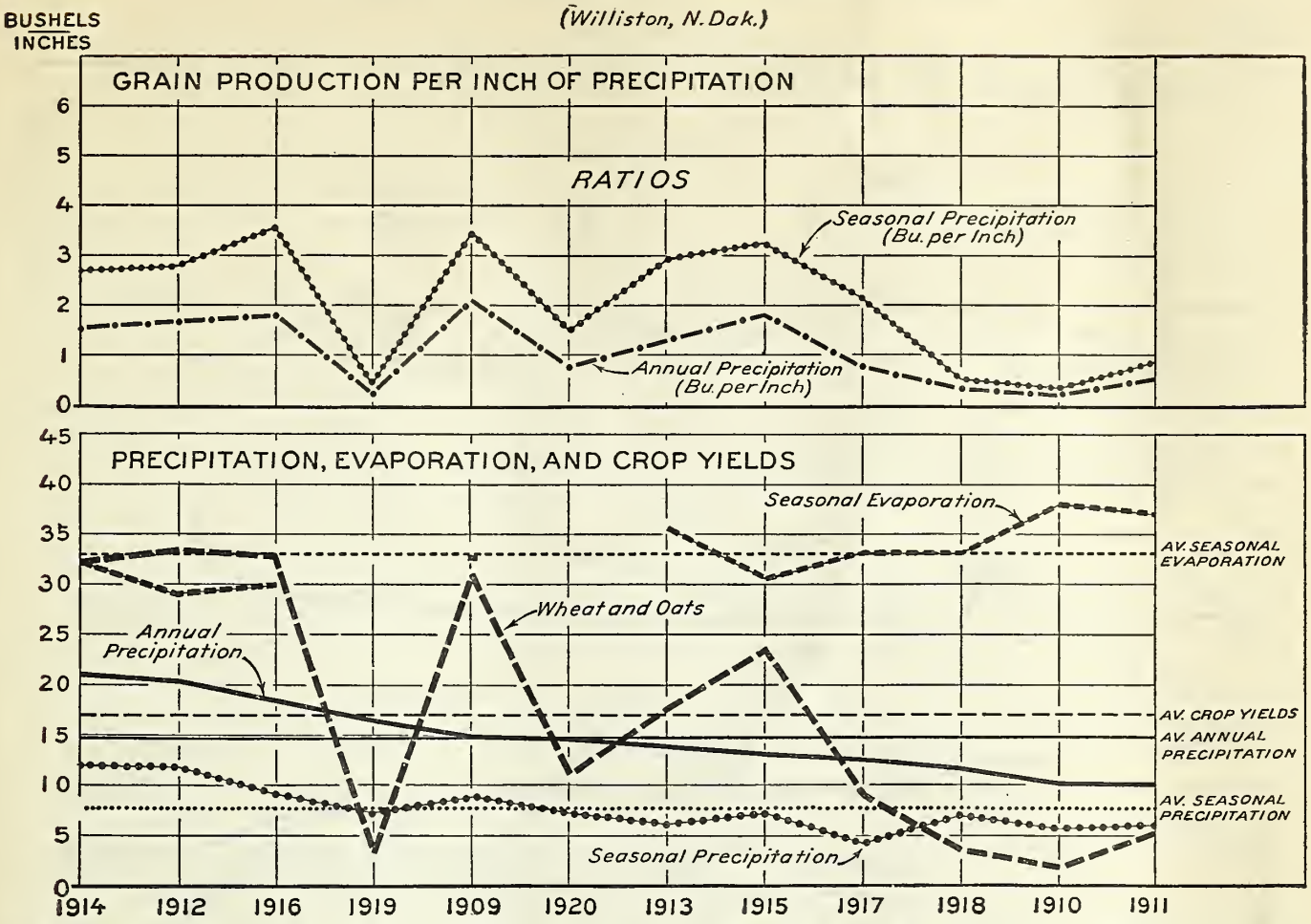


FIG. 50.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Spring wheat 19, oats 21, total 40; for a period of 12 years, at the Williston (N. Dak.) Field Station. (See Tables 7, 13, and 14)

TABLE 5.—*Mean annual and seasonal precipitation, seasonal evaporation, and crop yields, arranged, respectively, in order of their magnitude for 23 field stations in the Great Plains area*

SOUTHERN GROUP

Annual precipitation (inches)		Seasonal precipitation (inches)		Seasonal evaporation (inches)		Composite acre crop yields (bushels)
Lawton	28.51	Woodward	17.60	Big Spring	58.372	
Woodward	25.37	Lawton	17.45	Tucumcari	54.635	
Garden City	19.01	Dalhart	14.43	Garden City	52.152	
Amarillo	18.76	Amarillo	14.20	Amarillo	52.082	
Tucumcari	18.71	Garden City	14.26	Dalhart	51.828	
Dalhart	18.68	Tucumcari	13.97	Woodward	49.680	
Big Spring	17.80	Big Spring	12.06	Lawton	43.308	
Average	20.98	Average	14.85	Average	51.722	

NORTHERN GROUP

Hays	21.59	Hays	11.77	Hays	46.562	Dickinson	19.6
Colby	20.29	North Platte	11.36	Akron	43.116	Colby	19.2
North Platte	20.02	Colby	11.11	North Platte	41.955	Mandan	19.1
Akron	17.81	Ardmore	10.84	Colby	39.819	Sheridan	18.8
Moccasin	17.11	Edgeley	10.51	Scottshluff	37.391	Huntley	18.6
Edgeley	17.01	Mandan	10.13	Ardmore	36.919	Hays	18.2
Ardmore	16.69	Akron	9.71	Archer	36.897	Moccasin	17.7
Dickinson	16.05	Dickinson	9.55	Bellefourche	36.543	Edgeley	17.2
Mandan	15.88	Bellefourche	9.07	Assinniboine	35.214	Williston	17.0
Bellefourche	15.80	Moccasin	8.88	Sheridan	34.212	Bellefourche	16.9
Scottshluff	15.06	Scottsbluff	8.43	Mandan	34.211	Ardmore	16.3
Archer	14.81	Sheridan	7.99	Moccasin	33.348	North Platte	15.0
Sheridan	14.79	Archer	7.86	Williston	33.103	Assinniboine	12.1
Huntley	14.76	Williston	7.74	Dickinson	32.516	Scottsbluff	11.6
Williston	14.68	Huntley	7.54	Huntley	32.497	Akron	10.8
Assinniboine	12.36	Assinniboine	6.99	Edgeley	29.482	Archer	9.6
Average	16.54	Average	9.34	Average	36.487	Average	16.1
Grand average	17.89	Grand average	11.02	Grand average	41.123	Grand average	16.1

In Table 5 the stations are arranged in two groups, 7 southern and 16 northern stations. It shows the means of the annual and the seasonal precipitation and the seasonal evaporation for all stations. It also shows the composite crop yields for the northern group. The crop yields for the southern group have not been composited. This table will be found convenient for reference, as the means of each of the four factors presented are arranged so as to be readily compared.

The number of plats of each of the three grains used for this purpose at each station each year is shown in Table 6. These numbers range from 40 to 133 and average 75 each year per station, 1,199 each year for all stations, and 15,450 for all years at all stations. It is believed that this large number of determinations furnishes a sound basis for comparison with the meteorological data gathered from observations taken at the stations and that these comparisons will throw some light upon many problems that have been very obscure and concerning which many misconceptions exist. However, it must be constantly kept in mind that, although it seems necessary to use mathematical expressions in the presentation, mathematical exactness can not be expected in the conclusions. Some of the reasons for the lack of mathematical exactness are as follows:

(1) At some stations the number of plats averaged is as low as 40, while at others it is as high as 133, as shown in Table 6.

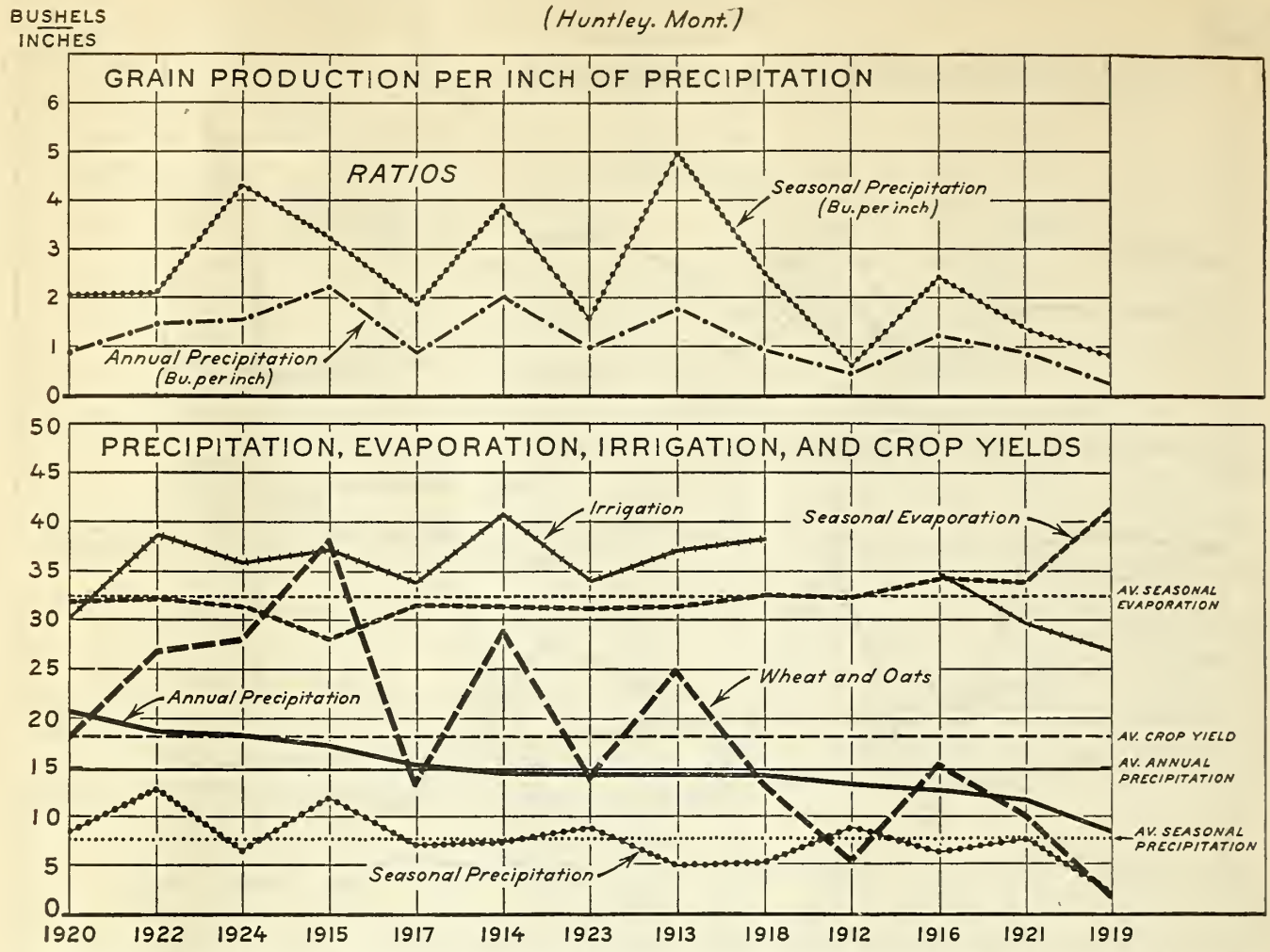


FIG. 51.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches, and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 25, spring wheat 36, oats 34, total 95; for a period of 13 years, at the Huntley (Mont.) Field Station. (See Tables 7, 12, 13, and 14)

(2) The period during which the experiments have been conducted at the several stations ranges from 8 to 18 years.

(3) In the grouping and regrouping of the data it becomes necessary to use the averages of averages and of ratios, the sums of averages, and the averages of sums. It is obvious that mathematical exactness can not be obtained where such sources of error exist.

(4) It is true that some of these errors might be eliminated by weighting the averages. But there are many other sources of inexactness that could not be so eliminated.

(5) It has been decided, therefore, to submit the figures as they are presented in Table 7, which shows clearly the relations in time, place, quantity, duration, and the number of plats upon which the data for each station are based.

Table 7 has been prepared to show the annual precipitation, the composite yields of winter wheat, spring wheat, and oats, the ratios between precipitation in inches and yields in bushels, and the relations between these factors for each year at each of the 16 stations for an aggregate period of 218 years.

The composite yields are computed for each station in the equivalents of bushels of wheat. The number of plats of each of these grains at each station is shown in Table 6. The yields per acre of each crop are given in Figures 2 to 33, inclusive, and the composite yields computed from these data are given in Table 7.

TABLE 6.—*Number of plats upon which wheat and oats were grown each year at each station and for various periods at 16 stations in the northern Great Plains area*

Field stations	Years at each station	Each year				For entire period			
		Wheat		Oats	Total	Wheat		Oats	Total
		Winter	Spring			Winter	Spring		
Williston	12	-------	19	21	40	-------	228	252	480
Assiniboine	9	32	30	58	120	288	270	522	1,080
Moccasin	17	6	25	31	62	102	425	527	1,054
Huntley	13	25	36	34	95	325	468	442	1,235
Dickinson	18	-------	25	27	52	-------	450	486	936
Mandan	11	-------	67	66	133	-------	737	726	1,463
Edgeley	17	-------	28	28	56	-------	476	476	952
Sheridan	8	23	37	50	110	184	296	400	880
Bellefourche	17	6	30	32	68	102	510	544	1,156
Ardmore	12	12	39	41	92	144	468	492	1,104
Scottsbluff	10	11	27	37	75	110	270	370	750
North Platte	18	25	19	23	67	450	342	414	1,206
Archer	11	13	30	34	77	143	330	374	847
Akron	16	17	23	31	71	272	368	496	1,136
Colby	11	41	-------	-------	41	451	-------	-------	451
Hays	18	40	-------	-------	40	720	-------	-------	720
Total	218	251	435	513	1,199	3,291	5,638	6,521	15,450
Average	-------	16	27	32	75	206	352	407	965

The ratios between precipitation and yields are obtained by dividing the yields expressed in bushels per acre by the annual precipitation expressed in inches per annum. These ratios also indicate the number of bushels of grain produced for each inch of annual precipitation.

TABLE 7.—*Annual precipitation, bushels of grain produced for each inch of precipitation, and composite annual acre yields of wheat and oats at 16 field stations in the northern Great Plains area*

Station, number of plats, and comparison factors	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	Means	Rank A	Rank B	Rank C
Assinnihoine, 120 plats:																							
Precipitation inches											20.01	7.70	11.98	9.40	10.78	13.35	10.80	14.86	12.38	12.36	16		
Ratio											2.25	.78	.52	.26	.89	.76	.50	.79	.96	.86		11	
Yield bushels											45.0	6.0	6.2	2.4	9.6	10.2	5.4	11.8	11.9	12.1			13
Williston, 40 plats:																							
Precipitation inches				14.72	10.02	10.01	20.29	13.79	21.00	13.06	18.44	12.47	11.49	16.34	14.58					14.68	15		
Ratio				2.10	.18	.52	1.65	1.28	1.53	1.79	1.78	.73	.30	.20	.75					1.07		5	
Yield bushels				30.9	1.8	5.2	33.4	17.7	32.2	23.4	32.8	9.1	3.5	3.3	11.0					17.0			9
Huntley, 95 plats:																							
Precipitation inches							13.17	14.15	14.30	17.08	12.53	15.13	14.06	8.32	20.51	11.58	18.56	14.17	18.20	14.76	14		
Ratio							.40	1.76	2.01	2.24	1.21	.86	.92	.22	.87	.87	1.44	.99	1.53	1.18		3	
Yield bushels							5.3	24.9	28.7	38.2	15.2	13.0	13.0	1.8	17.8	10.1	26.8	14.0	27.9	18.2			5
Sheridan, 110 plats:																							
Precipitation inches												13.95	14.48	9.71	14.60	11.23	16.30	16.77	21.25	14.79	13		
Ratio												.69	2.02	.10	1.77	.55	1.62	1.28	1.46	1.19		2	
Yield bushels												9.6	29.2	1.0	25.9	6.2	26.4	21.4	31.0	18.8			4
Archer, 77 plats:																							
Precipitation inches									14.80	15.50	11.90	17.74	16.96	11.77	20.86	11.59	11.25	14.68	15.85	14.81	12		
Ratio									.49	1.46	.33	.81	1.04	.14	.26	.87	.17	.68	.71	.63		15	
Yield bushels									7.3	22.6	3.9	14.4	17.7	1.6	5.4	10.1	1.9	10.0	11.2	9.6			16
Scottsbluff, 75 plats:																							
Precipitation inches							15.82	15.27	15.09	15.78	17.01	15.30	13.63	12.50	18.44	11.75				15.06	11		
Ratio							1.02	.77	.83	1.51	.36	.76	.68	.19	.85	.61				.76		13	
Yield bushels							16.2	11.7	12.5	23.8	6.1	11.7	9.3	2.4	15.7	7.2				11.7			14
Bellefourche, 68 plats:																							
Precipitation inches			13.52	17.62	12.51	6.62	13.57	14.45	13.08	21.14	13.13	13.74	14.42	14.99	28.08	13.31	20.55	17.00	20.76	15.80	10		
Ratio			1.33	1.68	.22	0	.15	.97	1.05	2.60	1.20	.52	1.08	.09	.85	.46	1.57	1.57	1.16	.97		8	
Yield bushels			18.0	29.6	2.8	0	2.0	14.0	13.7	54.9	15.8	7.1	15.6	1.3	23.8	6.1	32.2	26.7	24.0	16.9			10
Mandan, 133 plats:																							
Precipitation inches									23.79	23.97	15.47	11.58	12.10	13.75	12.89	14.83	15.99	15.68	14.70	15.88	9		
Ratio									1.76	1.53	1.65	1.20	1.04	.84	.47	.15	1.53	.75	1.63	1.14		4	
Yield bushels									41.9	36.6	25.5	13.9	12.6	11.6	6.0	2.2	24.4	11.8	23.9	19.1			3
Dickinson, 52 plats:																							
Precipitation inches		15.17	16.32	18.97	19.13	10.70	20.58	12.55	23.51	19.21	18.54	11.88	10.53	10.35	12.71	14.47	19.84	17.95	16.55	16.05	8		
Ratio		1.73	1.70	1.82	.99	.46	0	2.16	.57	2.26	1.62	.86	.54	.22	1.52	.39	1.73	1.19	1.66	1.19		1	
Yield bushels		26.2	27.8	34.6	19.0	4.9	0	27.1	13.3	43.4	30.1	10.2	5.7	2.3	19.3	5.6	34.3	21.3	27.4	19.6			1
Ardmore, 92 plats:																							
Precipitation inches								11.19	14.36	26.82	18.24	15.20	19.42	16.22	18.52	14.09	15.79	16.49	13.94	16.69	7		
Ratio								.13	0	1.47	1.27	.52	1.54	.81	1.49	1.37	0	1.53	.62	.90		10	
Yield bushels								1.4	0	39.3	23.1	7.9	29.9	13.1	27.6	19.3	0	25.2	8.6	16.3			11
Edgeley, 56 plats:																							
Precipitation inches	18.58	12.77	16.13	16.72	11.16	14.79	24.62	15.63	24.67	18.94	22.32	13.72	11.24	19.12	13.38	18.33	17.12			17.01	6		
Ratio	1.66	.88	.69	1.67	.44	.14	1.30	1.35	.84	2.04	.47	.74	1.04	.32	1.41	.81	1.13			1.00		7	
Yield bushels	30.8	11.3	11.1	27.9	4.9	2.1	31.9	21.1	20.7	38.6	10.4	10.2	11.7	6.1	18.9	14.8	19.3			17.2			8
Moccasin, 62 plats:																							
Precipitation inches			14.99	22.18	18.11	17.02	22.31	15.28	16.78	17.94	18.83	17.88	18.09	10.26	19.72	14.29	15.41	18.33	13.46	17.11	5		
Ratio			.48	1.67	.77	1.46	.14	1.88	1.30	1.93	.95	.37	1.07	.22	.67	.76	1.51	1.09	1.02	1.02		6	
Yield bushels			7.2	37.1	13.9	24.9	3.2	28.8	21.8	34.6	17.8	6.6	19.3	2.3	13.2	10.8	23.2	19.9	13.7	17.5			7
Akron, 71 plats:																							
Precipitation inches				21.36	17.12	15.72	21.62	14.94	18.75	22.81	14.83	17.92	14.16	21.99	22.48	14.97	16.84	16.86	12.62	17.81	4		
Ratio				.55	.54	.18	1.11	.30	1.13	1.25	.54	.64	.13	.44	.86	.46	.34	.33	.21	.56		16	
Yield bushels				11.8	9.2	2.9	23.9	4.5	21.1	28.4	8.0	11.5	1.9	9.6	19.3	6.9	5.8	5.5	2.6	10.8			15
North Platte, 67 plats:																							
Precipitation inches		25.94	21.62	23.27	12.18	13.68	20.89	17.88	16.27	33.33	17.07	16.49	17.75	24.59	21.58	15.92	20.27	24.48	17.18	20.02	3		
Ratio		.72	1.35	.65	.58	0	.35	.25	.35	.99	1.27	.23	.32	.76	1.02	.80	.38	.97	1.57	.70		14	
Yield bushels		18.7	29.2	15.2	7.1	0	7.4	4.4	5.7	33.0	21.6	3.8	5.6	18.8	22.1	12.8	7.8	23.8	27.0	14.7			12
Colby, 41 plats:																							
Precipitation inches									20.84	25.84	16.41	12.10	20.09	23.36	22.39	23.85	18.62	21.96	17.68	20.29	2		
Ratio									.54	.97	1.34	0	.85	1.29	1.41	1.00	1.21	.25	1.26	.92		9	
Yield bushels									11.2	25.1	22.0	0	17.0	30.1	31.5	23.9	22.5	5.5	22.3	19.2			9 2
Hays, 40 plats:																							
Precipitation inches		27.00	22.79	26.81	20.92	14.04	20.95	21.30	19.67	30.53	19.06	11.97	24.15	26.53	18.52	26.03	21.52	14.44	22.38	21.59	1		
Ratio		.43	.90	.0	1.55	.09	.69	.33	1.06	.56	1.74	.47	.59	.59	1.69	1.25	1.28	0	1.86	.84		12	
Yield bushels		11.7	20.6	0	32.5	1.3	14.5	7.1	20.8	17.2	33.2	5.6	14.3	15.7	31.3	32.6	27.6	0	41.7	18.2			6
Average:																							
Precipitation inches	18.58	20.22	17.50	20.21	15.14	12.82	19.38	15.13	18.35	21.57	16.92	14.05	15.28	15.58	18.13	15.31	17.06	17.20	16.69	16.54			
Ratio	1.66	.94	1.07	1.27	.66	.36	.68	1.02	.96	1.61	1.20	.64	.85	.42	1.05	.74	1.03	.88	1.20	.93			
Yield bushels	30.8	17.0	19.0	23.4	11.4	5.2	13.8	14.8	17.9	32.8	20.7	8.8	13.3	7.7	18.7	11.9	18.4	15.1	21.0	16.1			
Number of stations for each year [1]	1	4	6	8	8	8	10	11	14	14	15	16	16	16	16	15	14	13	13				

[1] 218 station years.

The number of years that these investigations have been conducted at each of the stations can be seen at a glance.

Only those stations having corresponding periods of the same years are mathematically comparable. But for the purpose of obtaining a rough approximation of the relations between the annual precipitation and crop yields it has seemed best to give the simple facts as shown by the records. Moreover, it is believed that any attempt to weight the averages from the several stations so as to make them more nearly comparable would result in no closer approximation to the truth than can be had by using the figures as they appear in Table 7.

Comparisons of the relations between precipitation and crop yields for the several years at any one station are not subject to the complications above mentioned. The stations, therefore, have been treated individually in the figures and tables that follow, and it is believed that these data are by far the most reliable of any now available bearing upon the relations between annual precipitation and crop yields.

There are some distinct advantages to be gained, however, by using the results from the entire period of 218 crop years at the 16 northern stations and making comparisons between the individual crop years regardless of the station at which the results were obtained; and also by comparing the means of the results obtained at each of the 16 stations with those obtained at all of the other stations. In making such comparisons it must be borne in mind, for the reasons already explained, that these results are not strictly comparable from a mathematical standpoint. Such comparisons nevertheless serve a useful purpose by showing the relations between crop yields and precipitation.

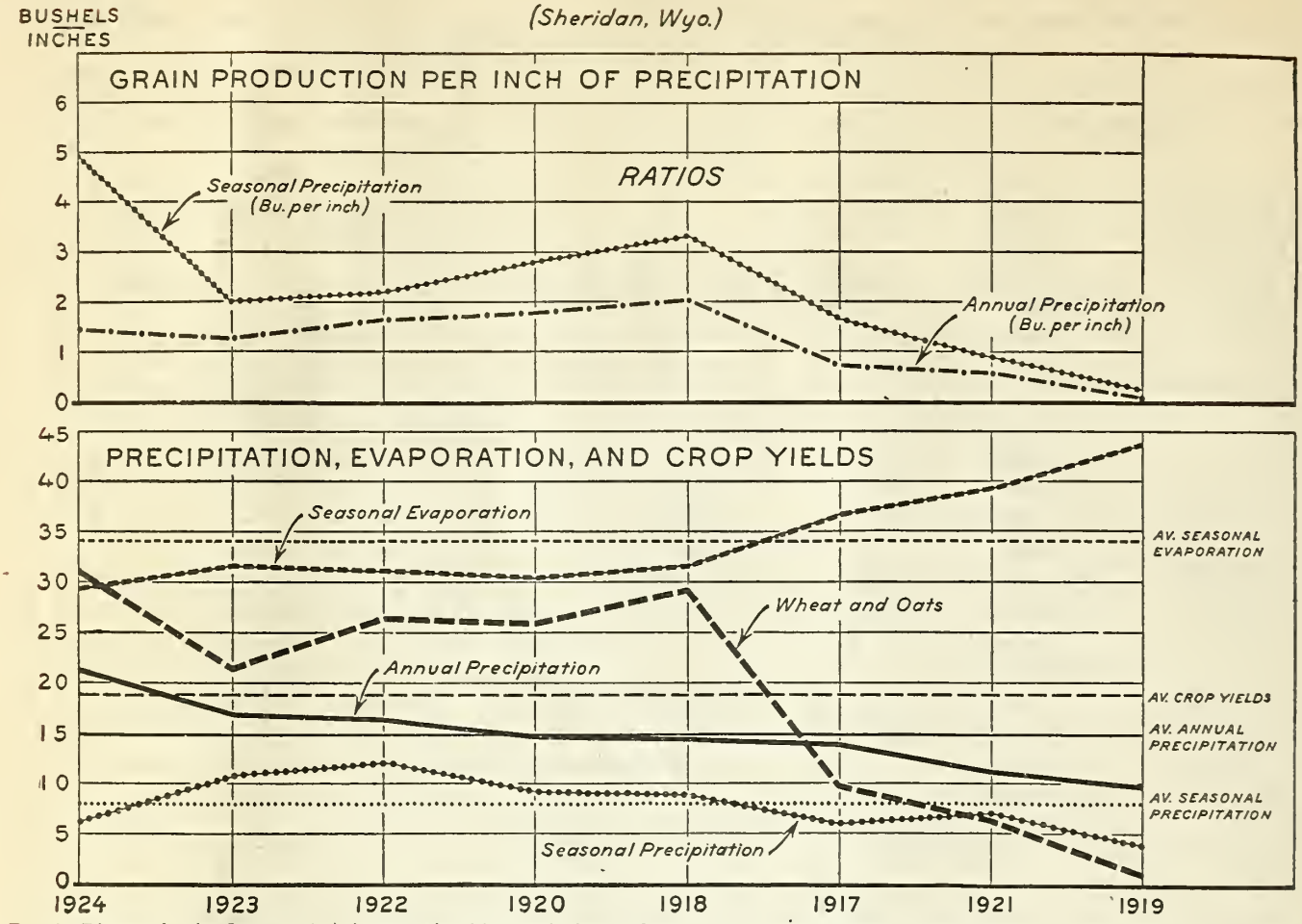


FIG. 52.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 23, spring wheat 37, oats 50, total 110; for a period of eight years, at the Sheridan (Wyo.) Field Station. (See Tables 7, 13, and 14)

It will be noted that the relative rank of the several stations for precipitation, ratios, and crop yields are given in the last three columns of Table 7, indicated as A, B, and C, respectively. The means of each of these factors, annual precipitation, ratios, and crop yields, are given in the column headed "Means."

In column A are given the ranks based on precipitation. As the stations were arbitrarily arranged in the inverse order of the magnitude of the annual precipitation, the ranks based on this factor appear in regular sequence from the bottom toward the top of the table. In column B are given the ranks based on the ratios and in column C the ranks based on crop yields.

If the relations between annual precipitation and crop yields were directly proportional, the relative ranks of crop yields would be the same as those of the annual precipitation, and the ratios would be constant for all crop years; but nothing even remotely approaching such an arrangement exists.

Of course, perfect regularity can not be expected, as it is well known that there are always present some inhibiting factors that will disturb perfect equilibrium; but where so little semblance of orderly arrangement exists it seems certain that the inhibiting factors have eliminated the effects of any directly proportional relationship that might have existed between annual precipitation and crop yields (fig. 48).

There is another method of comparison that might help to interpret the facts set forth in this table.

As the stations are arranged in the order of increasing magnitude of annual precipitation, it is obvious that the first 8 stations would show an average annual precipitation lower than the second 8 stations. The first 8 have an average of 14.77 inches, the second of 18.32 inches, a difference of 3.55 inches.

The mean crop yield for the first 8 is 15.43 bushels and for the second 16.69 bushels, a difference of 1.26 bushels. If the relations between precipitation and crop yields were directly proportional, the differences would be about the same, whereas the difference in precipitation is nearly three times that of yields. The mean ratio for the first group is 0.98 and for the second group 0.89, which reflects the discrepancies in the relations between precipitation and yields. This test gives the same indications as the previous ones, which is that the relations between precipitation and yields are not directly proportional. Many other interesting comparisons are made in considering the data of the individual stations which follow.

AVERAGE YIELDS OF WHEAT AND OATS

Table 7 gives the composite yields of wheat and oats for each year for the 16 field stations. By grouping these according to yields per acre, regardless of stations, the facts shown in Table 8 are presented.

Two bushels of oats are computed as approximately equivalent to one bushel of wheat. At 10 stations winter wheat, spring wheat, and oats are used for computing the composite yields. This is done by taking one-fourth of the sum of the yields in bushels of these three crops. At four of the stations, Williston, Dickinson, Mandan, and Edgeley, spring wheat and

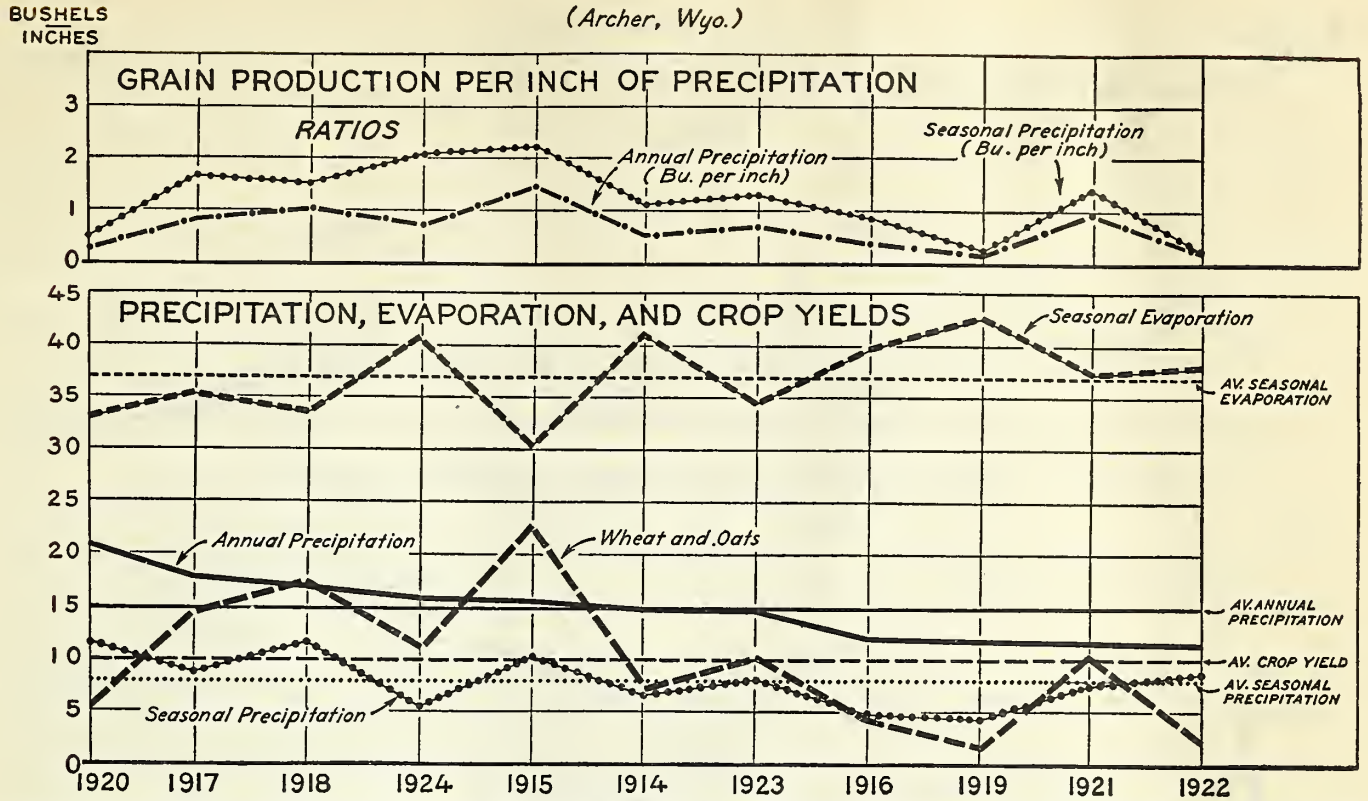


FIG. 53.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 13, spring wheat 30, oats 34, total 77; for a period of 11 years, at the Archer (Wyo.) Field Station. (See Tables 7, 13, and 14)

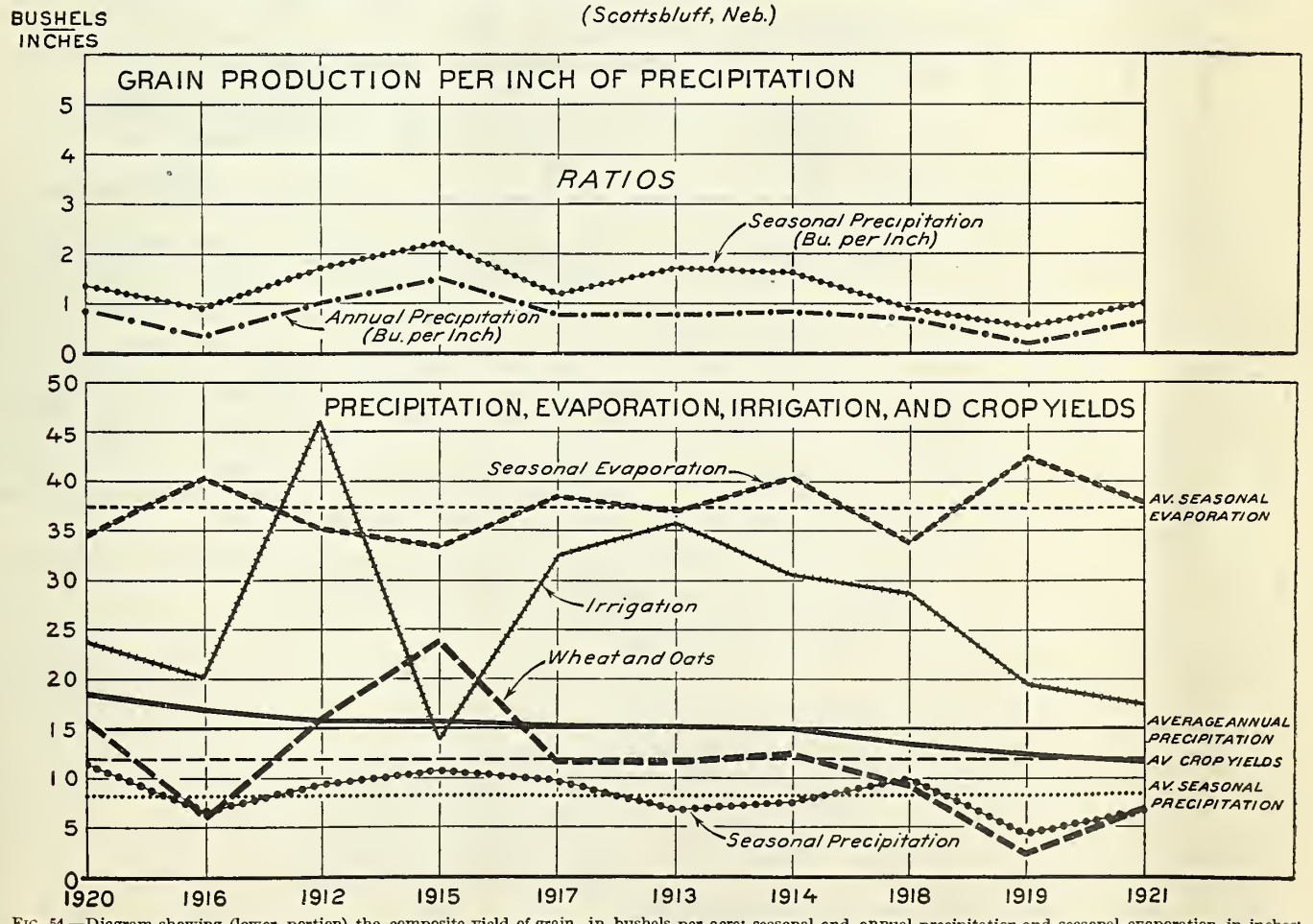


FIG. 54.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 11, spring wheat 27, oats 37, total 75; for a period of ten years, at the Scottsbluff (Nebr.) Field Station. (See Tables 7, 12, 13, and 14)

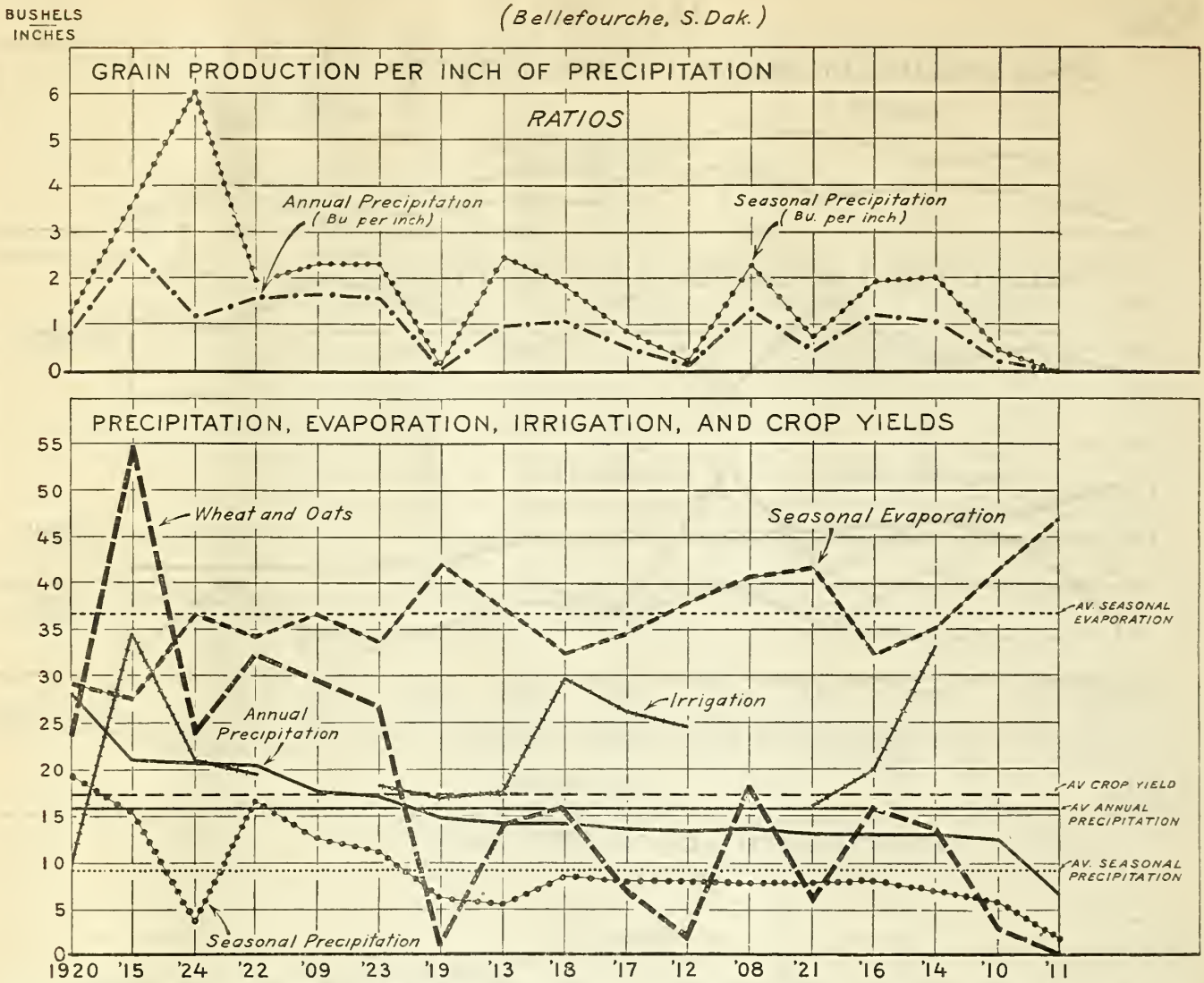


FIG. 55.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 6, spring wheat 30, oats 32, total 68; for a period of 17 years, at the Bellefourche (S. Dak.) Field Station. (See Tables 7, 12, 13, and 14)

oats only are used. The sum of the yields in bushels of these two crops is divided by 3 to obtain the composite yield. At Colby and Hays the actual yields in bushels of winter wheat only are used, neither spring wheat nor oats being well adapted to these locations. Average yields per acre calculated from 15,450 determinations covering 218 crop years are equivalent to 16.1 bushels of wheat per acre. (Table 7.)

It is generally believed by practical farmers that a crop of wheat yielding less than 10 bushels per acre is produced at a loss, but that higher yields may represent a profit if prices and production costs are normal. This division into two groups, representing unprofitable and profitable crops, is therefore of much interest to the practical farmer.

It will be seen from Table 9 that, taking the 16 stations collectively, 66 per cent of the 218 crop years are classed as profitable and 34 per cent as unprofitable. Expressed in other terms, about two years out of three were profitable and one year unprofitable. It is believed that this is a fair estimate of what may be expected throughout the northern Great Plains, extending as far south as central Kansas.

But when the stations are considered individually it is seen that there is a wide departure from this ratio. The station at Assiniboine, Mont., has a record of only nine years. For five of the nine years the annual precipitation was below normal and averaged only 10.5 inches. Two other years averaged 14.10 inches, but the crop year 1916 had 20.01 inches of annual precipitation. These adverse climatic conditions resulted in the production of but four crop yields above 10 bushels per acre and five below, or a ratio of 56 per cent below and 44 per cent above.

TABLE 8.—*Average composite yields of winter wheat, spring wheat, and oats grown by all methods for 218 crop years at 16 field stations in the northern Great Plains area*

Acre-yield data compared	Station years	
	Number	Proportion (per cent)
Total failure	8	3.67
Yields up to 5 bushels, inclusive	28	12.85
More than 5 and up to 10 bushels, inclusive	39	17.89
More than 10 and up to 15 bushels, inclusive	40	18.35
More than 15 and up to 20 bushels, inclusive	24	11.01
More than 20 and up to 25 bushels, inclusive	27	12.39
More than 25 and up to 30 bushels, inclusive	23	10.55
More than 30 and up to 35 bushels, inclusive	19	8.71
More than 35 and up to 40 bushels, inclusive	5	2.29
More than 40 and up to 55 bushels, inclusive	5	2.29
Total	218	100

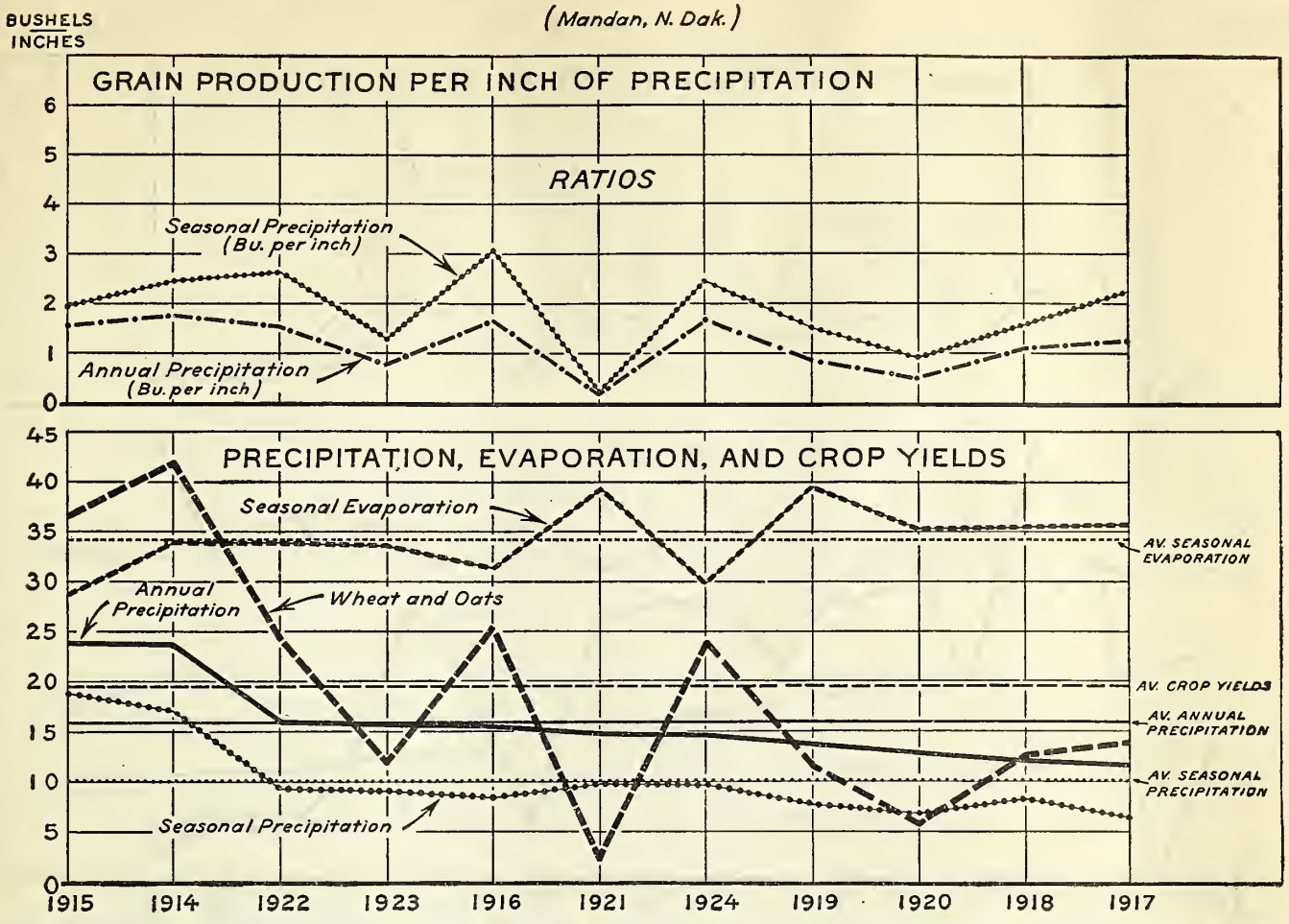


FIG. 56.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Spring wheat 67, oats 66, total 133; for a period of 11 years, at the Mandan (N. Dak.) Field Station. (See Tables 7, 13, and 14)

The station showing the lowest percentage of years when the yields fell below 10 bushels per acre is Huntley, Mont. This station has a record of 13 years. In only two of these years have the crop yields been below 10 bushels per acre, and in 11 years they have been above, or a ratio of 15 per cent below and 85 per cent above.

These two stations are both in Montana, about 200 miles apart. The altitude of Assinniboine is about 2,500 feet and that of Huntley 3,000 feet. The soil of the Assinniboine station is as well adapted to dry farming as that at Huntley, if not better. The general climatic conditions of the two stations are very similar. The annual precipitation at Huntley averaged 14.76 inches for the 13-year period and that at Assinniboine 12.36 inches for the 9-year period. But the average annual precipitation at Assinniboine for the 4-year period from August 1, 1911, to July 30, 1915, was 14.78 inches, and at Huntley it was 14.68. From these facts it seems probable that if the investigations at Assinniboine had been started in 1911, when they were at Huntley, there would have been no such differences in the results obtained at these two stations. Many other such comparisons might be made to account for the differences in the results from the individual stations.

Tables 10 and 11 are arranged on the same general plan as Table 9, except that the crop yields have been divided into 10 classes instead of 2 and that the numbers of crop years are used in Table 10 and the percentages of crop years in Table 11. The average crop yields also have been given in both Tables 10 and 11 and the average annual precipitation for each station has been given in Table 11, in order to facilitate comparisons.

TABLE 9.—*Comparison of composite small-grain acre yields below and above 10 bushels per acre, by station years, at 16 field stations in the northern Great Plains area*

Location	Station years with yields of—				Total
	10 bushels or less		More than 10 bushels		
	Number	Proportion (per cent)	Number	Proportion (per cent)	
Williston	5	42	7	58	12
Assinniboine	5	56	4	44	9
Moccasin	4	24	13	76	17
Huntley	2	15	11	85	13
Dickinson	5	28	13	72	18
Mandan	2	18	9	82	11
Edgeley	3	18	14	82	17
Sheridan	3	38	5	62	8
Bellefourche	6	35	11	65	17
Ardmore	5	42	7	58	12
Scottsbluff	4	40	6	60	10
North Platte	8	44	10	56	18
Archer	6	55	5	45	11
Akron	10	62	6	38	16
Colby	2	18	9	82	11
Hays	5	28	13	72	18
Total	75	34	143	66	218

It is believed that Tables 9, 10, and 11 are well worth careful study even if for no other purpose than to show the danger of making broad generalizations from inadequate data.

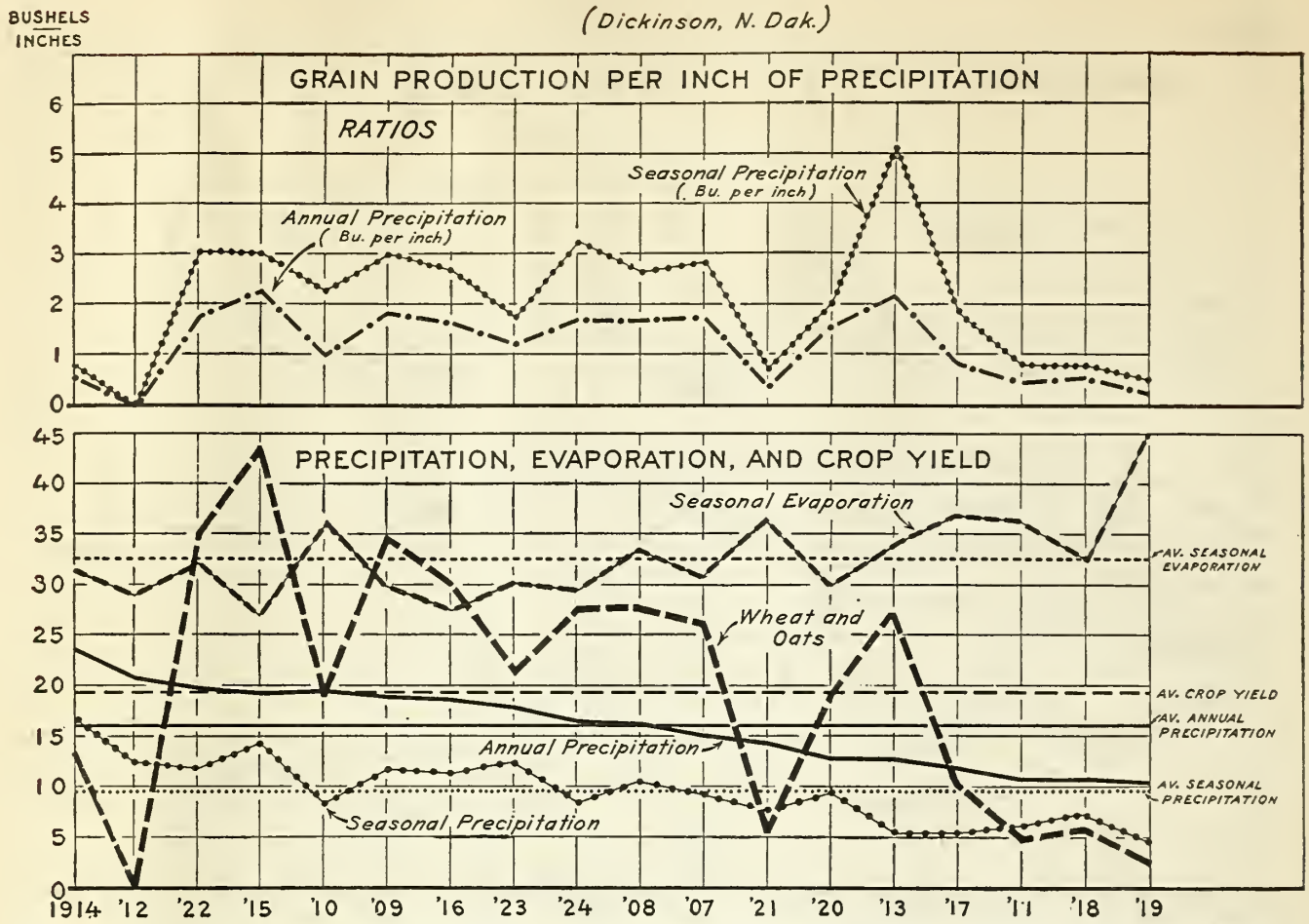


FIG. 57.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Spring wheat 25, oats 27, total 52; for a period of 18 years, at the Dickinson (N. Dak.) Field Station. (See Tables 7, 13, and 14)

TABLE 10.—*Distribution of crop yields, by station years, at 16 field stations in the northern Great Plains area*

Field stations	Number of years with respective acre yields											Average acre yields (bushels)
	Total failure	0 to 5 bushels	5 to 10 bushels	10 to 15 bushels	15 to 20 bushels	20 to 25 bushels	25 to 30 bushels	30 to 35 bushels	35 to 40 bushels	40 to 55 bushels	Total	
Williston		3	2	1	1	1		4			12	17.0
Assiniboine		1	4	3						1	9	12.1
Moccasin		2	2	4	3	3	1	1	1		17	17.5
Huntley		1	1	4	2	1	3		1		13	18.2
Dickinson	1	2	2	2	2	1	4	3		1	18	19.6
Mandan		1	1	4		2	1		1	1	11	19.1
Edgeley		2	1	6	2	2	1	2	1		17	17.2
Sheridan		1	2			1	3	1			8	18.8
Bellefourche	1	3	2	2	3	2	2	1		1	17	16.9
Ardmore	2	1	2	1	1	1	3		1		12	16.3
Scottsbluff		1	3	3	2	1					10	11.7
North Platte	1	2	5	1	3	3	2	1			18	14.7
Archer		3	3	3	1	1					11	9.6
Akron		4	6	2	1	2	1				16	10.8
Colby	1		1	1	1	4	1	2			11	19.2
Hays	2	1	2	3	2	2	1	4		1	18	18.2
Total or average	8	28	39	40	24	27	23	19	5	5	218	16.1
Percentage	3.67	12.85	17.89	18.35	11.01	12.39	10.55	8.71	2.29	2.29	100.00	

These considerations furnish just a little more weight to the steadily increasing evidence indicating that the annual rainfall is a very poor index to the crop yields in a region like the northern Great Plains, where the normal rainfall ranges from 15 to 20 inches per annum, and that it will never be possible to make an agricultural classification of this region on the basis of meteorological information. A knowledge of the climatic conditions throughout the United States is undoubtedly of inestimable value to the farmers of the entire country, and the daily weather reports and storm and frost warnings can not be too highly estimated as assisting farmers in their farm operations. But the agricultural possibilities of any given locality or farm can be determined in only one way, and that is by the experience of practical farmers.

RESULTS UNDER IRRIGATION AT HUNTLEY, BELLEFOURCHE, AND SCOTTSBLUFF

At three of the field stations—Huntley, Bellefourche, and Scottsbluff—the Office of Western Irrigation Agriculture of the Bureau of Plant Industry is conducting

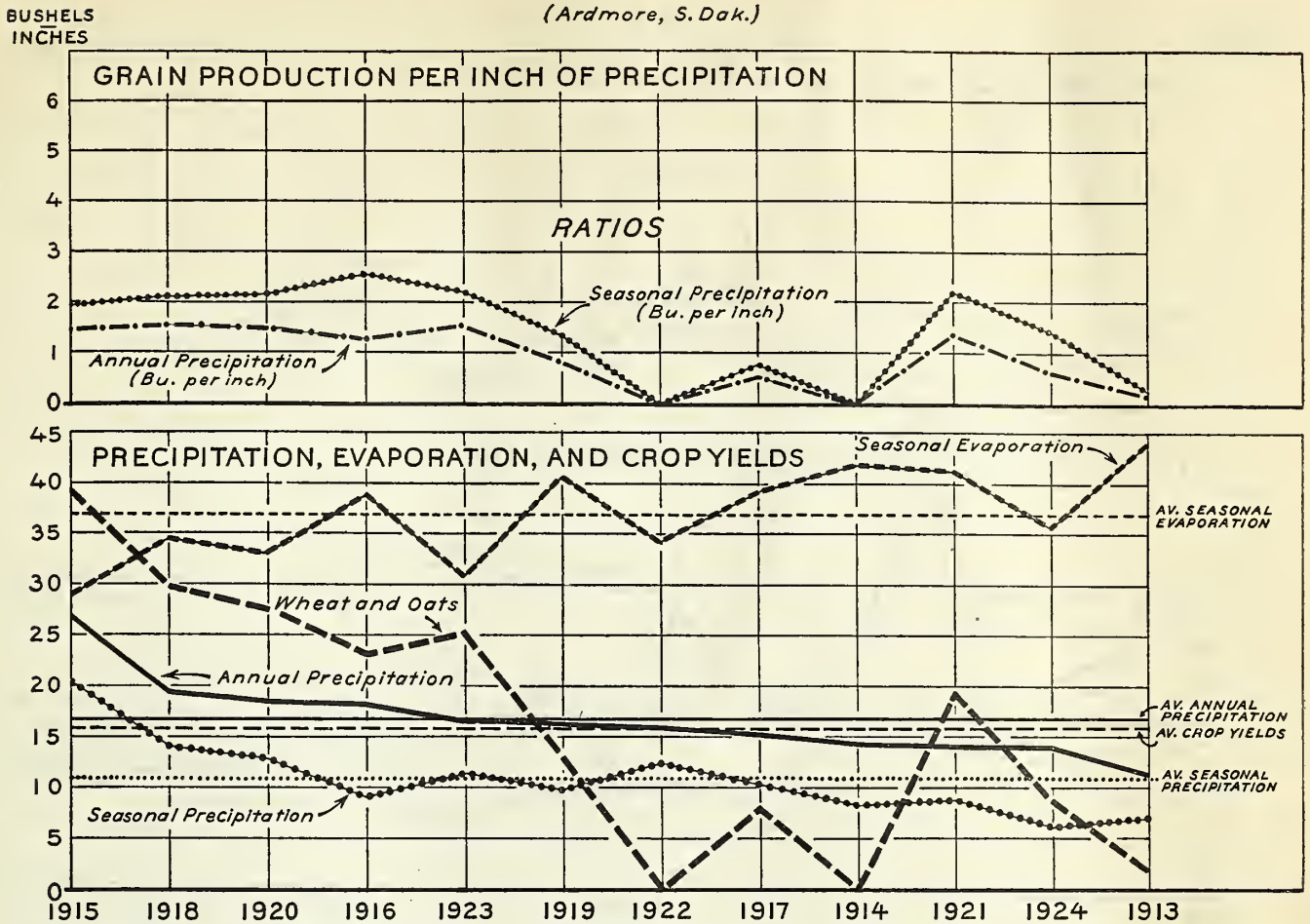


FIG. 58.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 12, spring wheat 39, oats 41, total 92; for a period of 12 years, at the Ardmore (S. Dak.) Field Station. (See Tables 7, 13, and 14)

TABLE 11.—*Distribution of small-grain crop yields reduced to percentages of the total number of station years at 16 field stations in the northern Great Plains area*

Field station	Percentage of years with respective acre yields										Total crop years	Average annual	
	Total failure	0 to 5 bushels	5 to 10 bushels	10 to 15 bushels	15 to 20 bushels	20 to 25 bushels	25 to 30 bushels	30 to 35 bushels	35 to 40 bushels	40 to 55 bushels		Acre yields (bushels)	Precipitation (inches)
Williston		25.00	16.67	8.33	8.33	8.34		33.33			12	17.0	14.68
Assiniboine		11.11	44.45	33.33						11.11	9	12.1	12.36
Moccasin		11.76	11.76	23.54	17.65	17.65	5.88	5.88	5.88		17	17.5	17.11
Huntley		7.69	7.69	30.77	15.39	7.69	23.08		7.69		13	18.2	14.76
Dickinson	5.56	11.11	11.11	11.11	11.11	5.56	22.22	16.67		5.55	18	19.6	16.05
Mandan		9.09	9.09	36.36		18.18	9.09		9.09	9.10	11	19.1	15.88
Edgeley		11.76	5.88	35.30	11.76	11.77	5.88	11.77	5.88		17	17.2	17.01
Sheridan		12.50	25.00			12.50	37.50	12.50			8	18.8	14.79
Bellefourche	5.88	17.65	11.76	11.77	17.65	11.76	11.77	5.88		5.88	17	16.9	15.80
Ardmore	16.67	8.33	16.67	8.33	8.33	8.33	25.00		8.34		12	16.3	16.69
Scottsbluff		10.00	30.00	30.00	20.00	10.00					10	11.7	15.06
North Platte	5.56	11.11	27.77	5.56	16.67	16.66	11.11	5.56			18	14.7	20.02
Archer		27.27	27.27	27.27	9.09	9.10					11	9.6	14.81
Akron		25.00	37.50	12.50	6.25	12.50	6.25				16	10.8	17.81
Colby	9.09		9.09	9.09	9.09	36.36	9.09	18.19			11	19.2	20.29
Hays	11.11	5.56	11.11	16.67	11.11	11.11	5.56	22.22		5.55	18	18.2	21.59
Total or average											218	16.1	16.54

investigations with the same crops as those used in these investigations. That office has kindly consented to allow the use of some of its results. The periods of time covered by these two lines of investigations did not correspond entirely; the number of plats used for each of the three grains was not so great as in the dry-land investigations, and there were other factors which make any precise comparison of them with the dry-land yields of doubtful value. But the results are given in Table 12, and they are shown in Figures 51, 54, and 55 for these three stations by the line marked "Irrigation." They have little significance except to show that irrigation farming is by no means exempt from the influence of inhibiting factors and that yields are nearly as erratic under irrigation as in dry farming.

At Huntley the yields under irrigation are consistently higher except for the year 1915 when they were slightly exceeded by the dry-land yields. They were fairly uniform, ranging from about 27 bushels to about 40 bushels per acre.

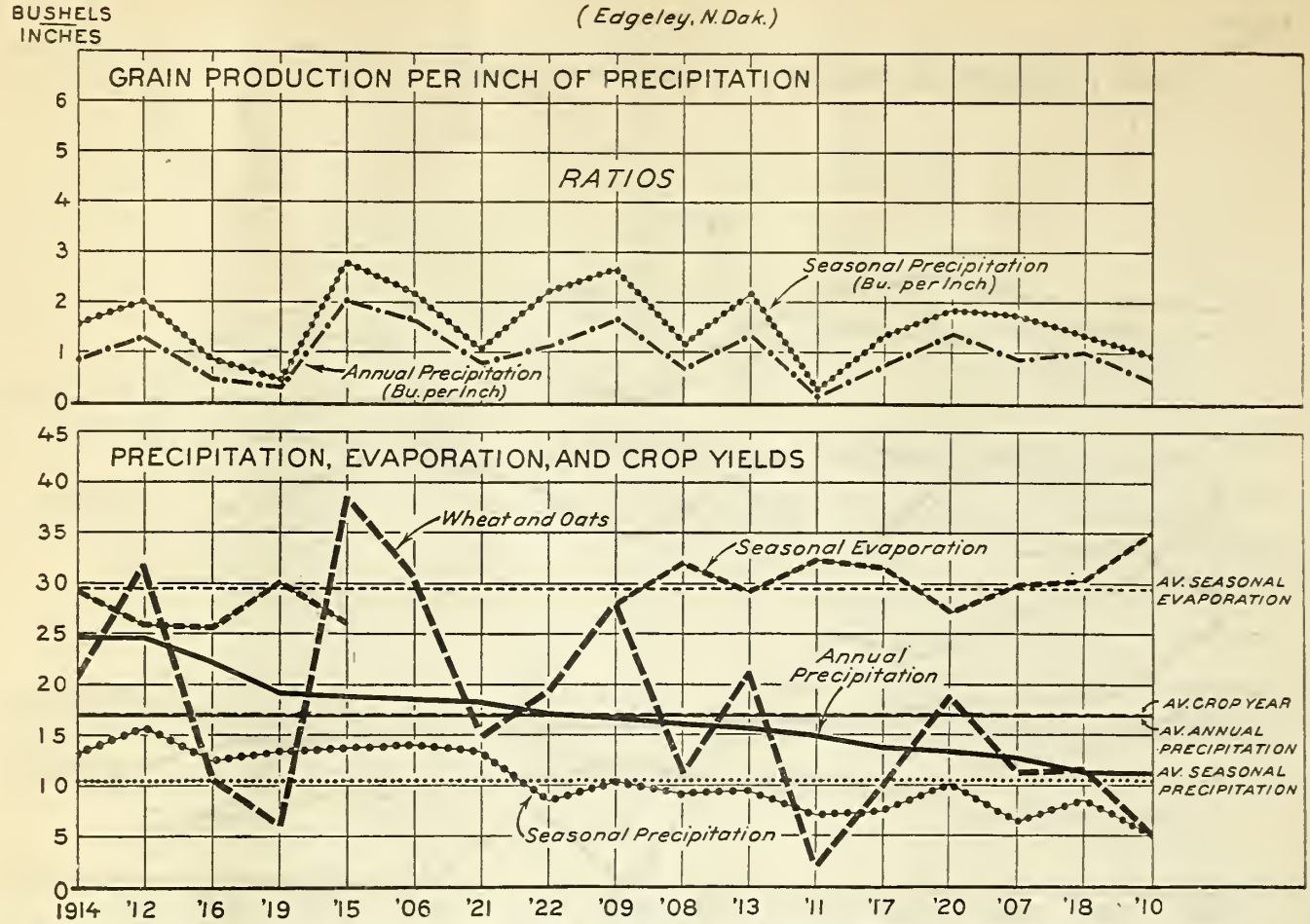


FIG. 59.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Spring wheat 28, oats 28, total 56; for a period of 17 years, at the Edgeley (N. Dak.) Field Station. (See Tables 7, 13, and 14)

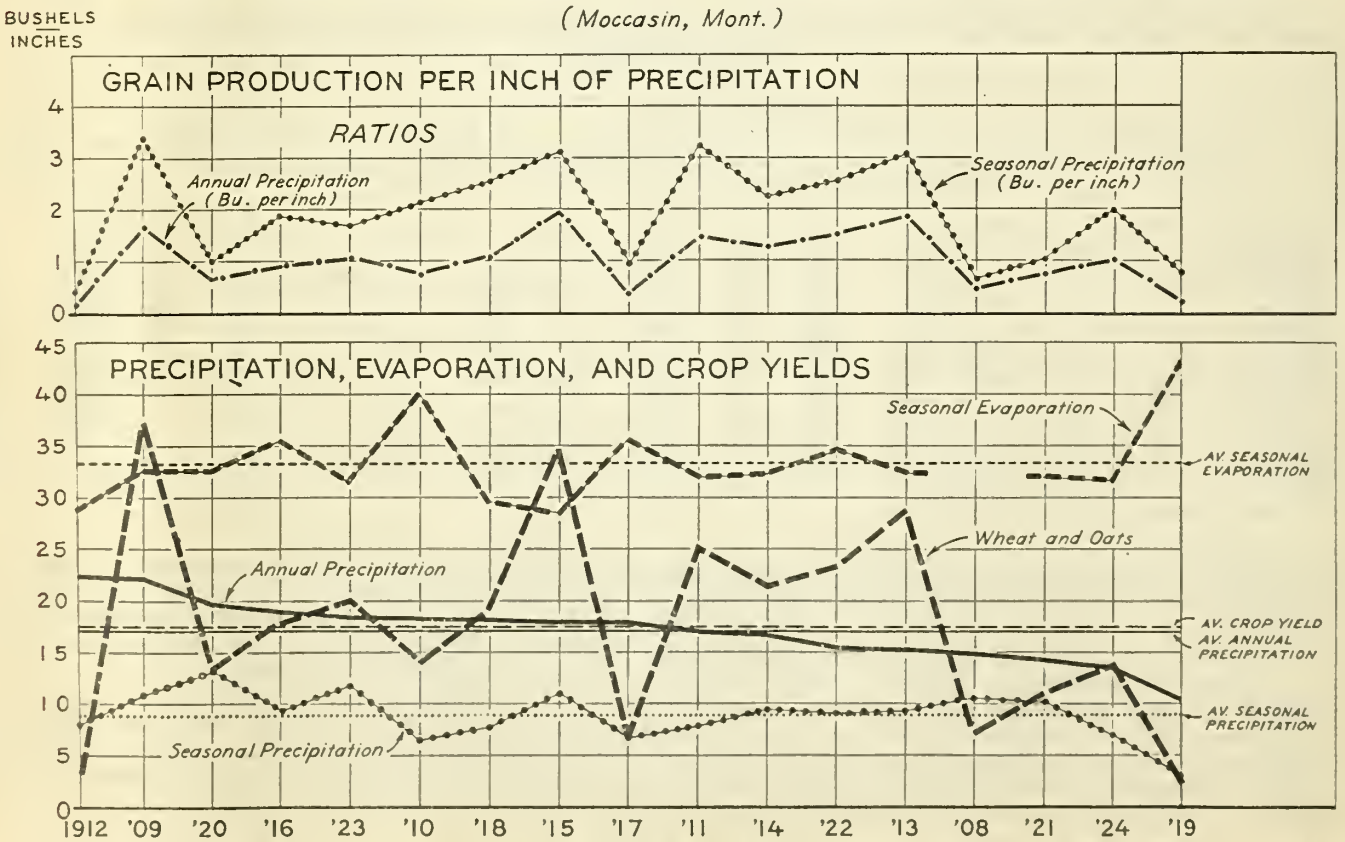


FIG. 60.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 6, spring wheat 25, oats 31, total 62; for a period of 17 years, at the Moccasin (Mont.) Field Station. (See Tables 7, 13, and 14)

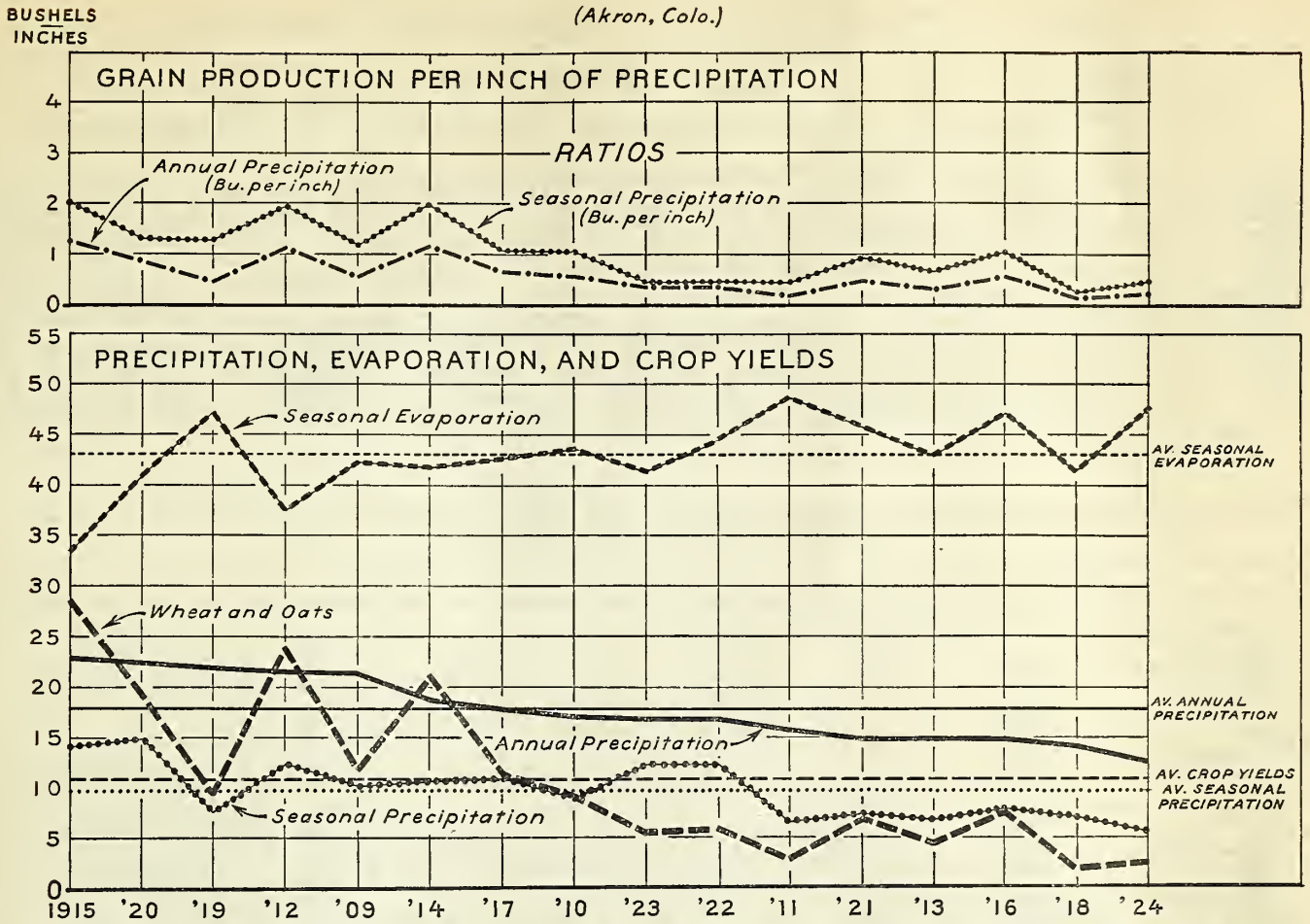


FIG. 61.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 17, spring wheat 23, oats 31, total 71; for a period of 16 years, at the Akron (Colo.) Field Station. (See Tables 7, 13, and 14)

At Bellefourche the irrigation yields are far less uniform or consistent than at Huntley. They range from 10 to nearly 35 bushels and are about as erratic, from year to year, as are the dry-land yields. They are lower than the dry-land yields in 5 out of 13 years. The dry-land yields in 1915 were about 55 bushels, while those under irrigation were only about 35 bushels.

TABLE 12.—*Composite yields of winter wheat, spring wheat, and oats under irrigation at Huntley, Bellefourche, and Scottsbluff field stations*

Year	Acre yields (bushels)			Year	Acre yields (bushels)		
	Huntley	Belle-fourche	Scotts-bluff		Huntley	Belle-fourche	Scotts-bluff
1912	----------	24.7	46.1	1919	26.7	17.1	19.4
1913	37.1	17.5	35.8	1920	30.0	10.2	23.8
1914	40.8	33.0	30.5	1921	29.6	16.0	17.5
1915	37.2	34.9	14.0	1922	38.5	19.7	----------
1916	34.9	20.0	20.3	1923	34.0	18.3	----------
1917	33.8	26.3	32.7	1924	35.8	20.8	----------
1918	38.2	29.9	28.8				

At Scottsbluff the irrigation yields ranged from about 14 to 46 bushels. In only one year, 1915, did the irrigation yields fall below dry-land yields. They were more erratic than at Huntley, but not quite so much so as at Bellefourche.

RELATIONS BETWEEN CROP YIELDS AND EVAPORATION

Although evaporation data are included for all stations and have been included in most of the diagrams, this factor has not heretofore entered into the discussions. The reason for this omission is that the Weather Bureau has not given the subject of evaporation much attention and has no evaporation data comparable with its data upon other meteorological factors for its observation stations. If as much information were available concerning evaporation throughout the United States as there is concerning precipitation, it might be of greater value in estimating the crop-producing possibilities of different regions than is the annual precipitation; for evaporation is an integration of several other important meteorological factors, such as precipitation, temperature, wind velocity, and relative humidity. Table 13 gives the seasonal evaporation for the 16 northern field stations, shown graphically in Figures 49 to 66, inclusive. These data were obtained by making daily measurements of the evaporation from the surface of the water contained in tanks 6 feet in diameter and 2 feet deep, sunk 20 inches in the ground. The water level was kept at about 4 inches below the top of the tank. The season of observation was the six months from April to September, inclusive, each year at each station.

RELATIONS BETWEEN CROP YIELDS AND SEASONAL PRECIPITATION

Figures 49 to 66, inclusive, show graphically the relations between composite yields of wheat and oats and seasonal precipitation for the 16 stations in the northern Great Plains. Table 14 presents these same data in statistical form.

TABLE 13.—*Average seasonal evaporation at 16 field stations in the northern Great Plains area*

Field stations	Number of years	Average evaporation (inches)																			
		1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	Mean
Williston	10			32.586	37.981	37.105	29.078	35.479	32.205	30.454	29.940	33.143	33.054							33.103
Assiniboine	9										30.558	34.638	36.473	39.980	36.985	38.302	34.390	32.505	33.097	35.214
Moccasin	16			32.607	40.135	32.242	28.770	32.326	32.272	28.492	35.529	35.673	29.711	43.186	32.576	32.075	34.750	31.533	31.689	33.348
Huntley	13						32.293	31.352	31.320	27.852	34.180	31.459	32.507	41.425	31.763	33.729	32.149	31.122	31.306	32.497
Dickinson	18	30.633	33.375	29.518	36.158	36.441	28.998	33.870	31.139	26.628	27.081	36.679	32.362	44.629	30.042	36.104	31.990	30.072	29.577	32.516
Mandan	11								33.949	28.616	31.277	35.682	35.499	39.591	35.251	39.262	33.855	33.536	29.799	34.211
Edgeley	14	29.927	32.121	28.047	35.096	32.393	25.950	29.220	29.189	26.053	25.562	31.632	30.271	30.097	27.185					29.482
Sheridan	8											36.665	31.567	43.663	30.472	39.238	31.086	31.581	29.424	34.212
Bellefourche	17		40.965	36.871	41.715	46.701	37.744	37.139	35.111	27.457	32.482	34.819	32.566	42.102	28.903	41.998	34.392	33.713	36.547	36.543
Ardmore	12							44.135	41.777	28.908	38.870	39.261	34.533	40.624	33.082	41.167	34.207	30.853	35.607	36.919
Scottsbluff	10						35.183	37.136	40.428	33.476	40.277	38.633	33.849	42.539	34.438	37.953				37.391
North Platte	18	41.319	41.936	40.423	46.564	49.702	41.678	51.456	47.441	35.469	43.603	40.578	41.849	40.126	36.376	42.782	40.973	34.209	38.705	41.955
Archer	11								40.935	30.363	39.612	35.349	33.520	42.660	33.083	37.278	37.968	34.445	40.655	36.897
Akron	16			42.353	43.621	48.818	37.696	43.053	41.863	33.409	47.166	42.709	41.422	47.232	40.912	45.903	44.579	41.429	47.688	43.116
Colby	11								43.743	31.657	45.532	38.720	41.375	39.641	32.721	39.363	42.585	37.371	45.306	39.819
Hays	18	44.648	44.381	47.471	43.819	59.824	46.965	58.283	47.096	33.277	50.231	50.469	47.569	40.996	39.776	44.557	47.320	42.803	48.622	46.562
Mean																				36.487

TABLE 14.—*Seasonal precipitation and ratios of composite yields of wheat and oats produced from 1 inch of seasonal precipitation at 16 field stations in the northern Great Plains area*

Field station and comparison factors	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	Average
Assiniboine:																				
Seasonal precipitation—inches											12.90	3.30	2.77	3.58	6.66	8.47	6.60	11.22	7.46	6.99
Ratio—bushels											3.49	1.82	2.24	.67	1.44	1.20	.82	1.05	1.60	1.59
Williston:																				
Seasonal precipitation—inches				8.92	5.62	6.09	11.91	6.07	12.00	7.23	9.21	4.21	6.98	7.25	7.35					7.74
Ratio—bushels				3.47	.32	.85	2.80	2.92	2.68	3.24	3.56	2.16	.50	.46	1.50					2.04
Huntley:																				
Seasonal precipitation—inches							8.83	5.00	7.35	11.83	6.31	7.01	5.25	2.21	8.54	7.59	12.63	8.91	6.49	7.54
Ratio—bushels							.60	4.98	3.90	3.23	2.41	1.85	2.48	.82	2.08	1.33	2.12	1.57	4.29	2.44
Sheridan:																				
Seasonal precipitation—inches												5.92	8.80	3.84	9.25	7.06	12.05	10.71	6.29	7.99
Ratio—bushels												1.62	3.32	.26	2.80	.88	2.19	1.99	4.93	2.25
Archer:																				
Seasonal precipitation—inches									6.55	10.16	4.64	8.66	11.52	4.24	11.50	7.31	8.59	7.91	5.32	7.86
Ratio—bushels									1.11	2.22	.84	1.66	1.54	.25	.47	1.38	.22	1.26	2.10	1.19
Scottsbluff:																				
Seasonal precipitation—inches							9.44	6.86	7.70	10.78	6.75	9.94	10.12	4.40	11.54	6.80				8.43
Ratio—bushels							1.72	1.71	1.62	2.21	.89	1.18	.92	.55	1.36	1.06				1.32
Bellefourche:																				
Seasonal precipitation—inches			7.84	12.75	5.76	1.92	8.07	5.68	6.74	15.38	8.01	7.99	8.58	6.22	19.37	7.82	16.52	11.48	3.98	9.07
Ratio—bushels			2.30	2.32	.49	0	.25	2.46	2.03	3.57	1.97	.89	1.82	.21	1.23	.78	1.95	2.33	6.03	1.80
Mandan:																				
Seasonal precipitation—inches									17.15	18.89	8.42	6.36	8.21	7.64	6.83	9.84	9.31	9.09	9.72	10.13
Ratio—bushels									2.44	1.94	3.03	2.19	1.53	1.52	.88	.23	2.62	1.30	2.46	1.83
Dickinson:																				
Seasonal precipitation—inches		9.18	10.46	11.53	8.35	6.01	12.46	5.31	16.54	14.41	11.26	5.48	7.12	4.60	9.40	7.50	11.57	12.23	8.44	9.55
Ratio—bushels		2.85	2.66	3.00	2.28	.82	0	5.10	8.80	3.01	2.67	1.86	.80	.50	2.05	.75	2.97	1.74	3.25	2.06
Ardmore:																				
Seasonal precipitation—inches								6.93	8.24	20.34	9.03	10.26	14.08	9.72	12.85	8.73	12.45	11.38	6.00	10.84
Ratio—bushels								.19	0	1.93	2.56	.77	2.12	1.35	2.15	2.21	0	2.21	1.43	1.41
Edgeley:																				
Seasonal precipitation—inches	14.03	6.44	9.18	10.40	5.08	7.09	15.73	9.53	13.23	13.81	12.48	7.54	8.58	13.45	10.22	13.37	8.56			10.51
Ratio—bushels	2.20	1.75	1.21	2.68	.97	.30	2.03	2.21	1.56	2.80	.83	1.35	1.36	.45	1.85	1.11	2.25			1.58
Moccasin:																				
Seasonal precipitation—inches			10.57	10.90	6.50	7.69	7.93	9.32	9.38	11.06	9.45	6.74	7.63	3.00	13.14	10.13	9.07	11.73	6.88	8.88
Ratio—bushels			.68	3.40	2.14	3.24	.40	3.09	2.32	3.13	1.88	.98	2.53	.77	1.00	1.07	2.56	1.70	1.99	1.93
Akron:																				
Seasonal precipitation—inches				10.20	8.87	6.60	12.32	6.83	10.67	14.17	7.69	10.83	7.02	7.61	14.87	7.44	12.26	12.38	5.63	9.71
Ratio—bushels				1.16	1.04	.44	1.94	.66	1.98	2.00	1.04	1.06	.27	1.26	1.30	.93	.47	.44	.46	1.03
North Platte:																				
Seasonal precipitation—inches		10.11	14.49	14.11	5.61	7.79	8.22	10.10	9.08	23.52	7.73	8.25	9.33	17.15	12.97	7.86	12.93	18.34	7.00	11.36
Ratio—bushels		1.85	2.02	1.08	1.27	0	.90	.44	.63	1.40	2.79	.46	.60	1.10	1.70	1.63	.60	1.30	3.86	1.31
Colby:																				
Seasonal precipitation—inches									11.61	18.79	8.58	8.14	5.26	11.45	16.03	11.49	10.71	15.81	4.35	11.11
Ratio—bushels									.96	1.34	2.56	0	3.23	2.63	1.97	2.08	2.10	.35	5.13	2.03
Hays:																				
Seasonal precipitation—inches		14.72	14.03	15.37	9.45	6.39	9.09	12.58	10.24	20.97	10.36	6.94	11.51	15.07	10.13	13.27	14.24	10.88	6.62	11.77
Ratio—bushels		.80	1.47	0	3.44	.20	1.60	.56	2.03	.82	3.20	.81	1.24	1.04	3.08	2.46	1.94	0	6.30	1.72

QUANTITY OF WHEAT PRODUCED FOR EACH INCH OF RAINFALL

The data contained in Table 7 have been expressed graphically in Figures 49 to 64, inclusive. The number of plats used in growing each of the three grains is given in the legends of the several diagrams. The lower portion of each figure shows in graphic form the annual and seasonal precipitation, the composite yields, and the evaporation. Unlike Table 7, in which the respective years are arranged in chronological order, these diagrams show the years in the order of the magnitude of their annual precipitation, the year of highest annual precipitation being at the left and the lowest at the right.

The reader therefore has before him in these 16 diagrams all of the essential meteorological and crop-yield factors necessary to enable him to see at a glance the relations that have existed between these factors during all of the years covered by these investigations at each of the 16 stations for a period aggregating 218 years.

If the relations between annual precipitation and crop yields were directly proportional, the ratios for all the years at any given station would fall upon a single straight horizontal line across the figure. The location of this horizontal line with reference to the scale at the left-hand side of each figure would be determined by the ratio between the mean annual precipitation and the

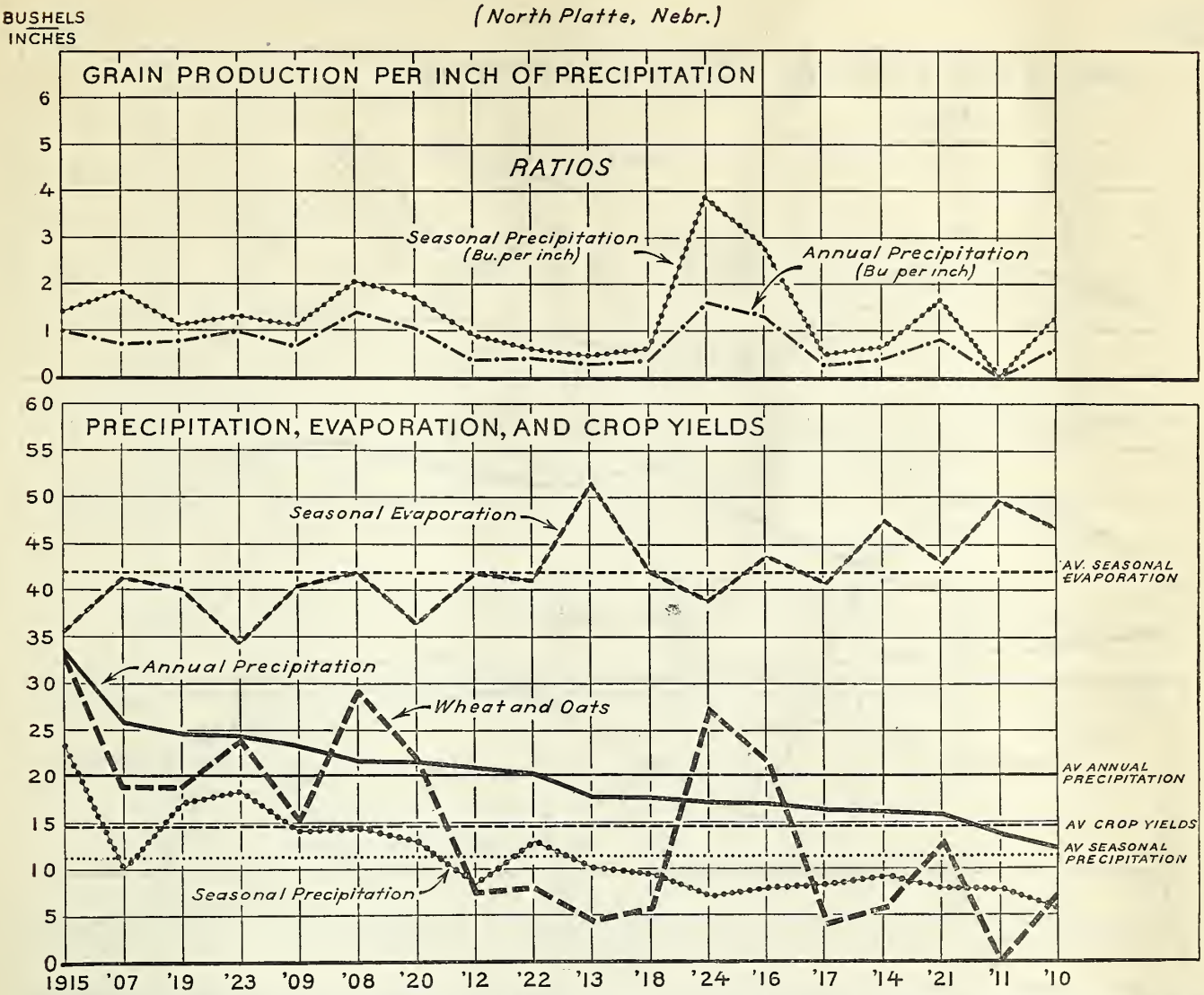


FIG. 62.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat 25, spring wheat 19, oats 23, total 67; for a period of 18 years, at the North Platte (Nebr.) Field Station. (See Tables 7, 13, and 14)

mean annual crop yield for that station for the entire period of observation. The same would be true of the ratios between seasonal precipitation and yields.

It is a well-established fact that the annual precipitation is sometimes so low in the Great Plains area that no seed is produced, and therefore there are no grain yields. In such instances the ratio point would be zero. When the crop yields are as low as 5 bushels per acre, the ratio point would be expected to show a marked depression. But such instances are not common. Yields of 5 bushels or less occurred in only 36 of the 218 years, and many, probably most, of the instances were due wholly, or in part, to causes other than deficient annual precipitation. We should therefore expect to find that departures from the horizontal in the ratio lines would be confined to less than one-fifth of the period of observation at each station, or from two to four years at any station. If this were true, we would then expect that the ratio lines beginning at the left-hand side of each figure would extend in an approximately horizontal direction for about four-fifths of the distance across, and would then curve sharply downward through the remaining one-fifth of the distance to the right-hand margin. An examination of each of the 16 Figures 49 to 64, or of Figure 65, will convince anyone that such is very far from being the case. In fact, horizontal ratio lines, even between any two adjacent points, are conspicuous by their rarity.

What is the explanation of the very erratic differences in ratios at the same station with the same crops, in different years, when the annual precipitation is practically the same? The obvious answer seems to be that there are always present certain factors other than deficient annual precipitation that inhibit directly proportional relations between annual precipitation and crop yields. Among these inhibiting factors are inopportune distribution of rainfall, hailstorms, high winds, hot winds, and their concomitants, soil blowing and breaking or beating down of crops; also diseases, insects, and many others which are described more in detail elsewhere.

These inhibiting factors vary widely in their frequency, in their potency, and in the relations that they bear to one another. Sometimes they work in conjunction and sometimes in opposition to one another. Sometimes beneficient influences that cause a very rapid growth of crop plants also create an equally favorable environment for the parasites that prey upon the crop

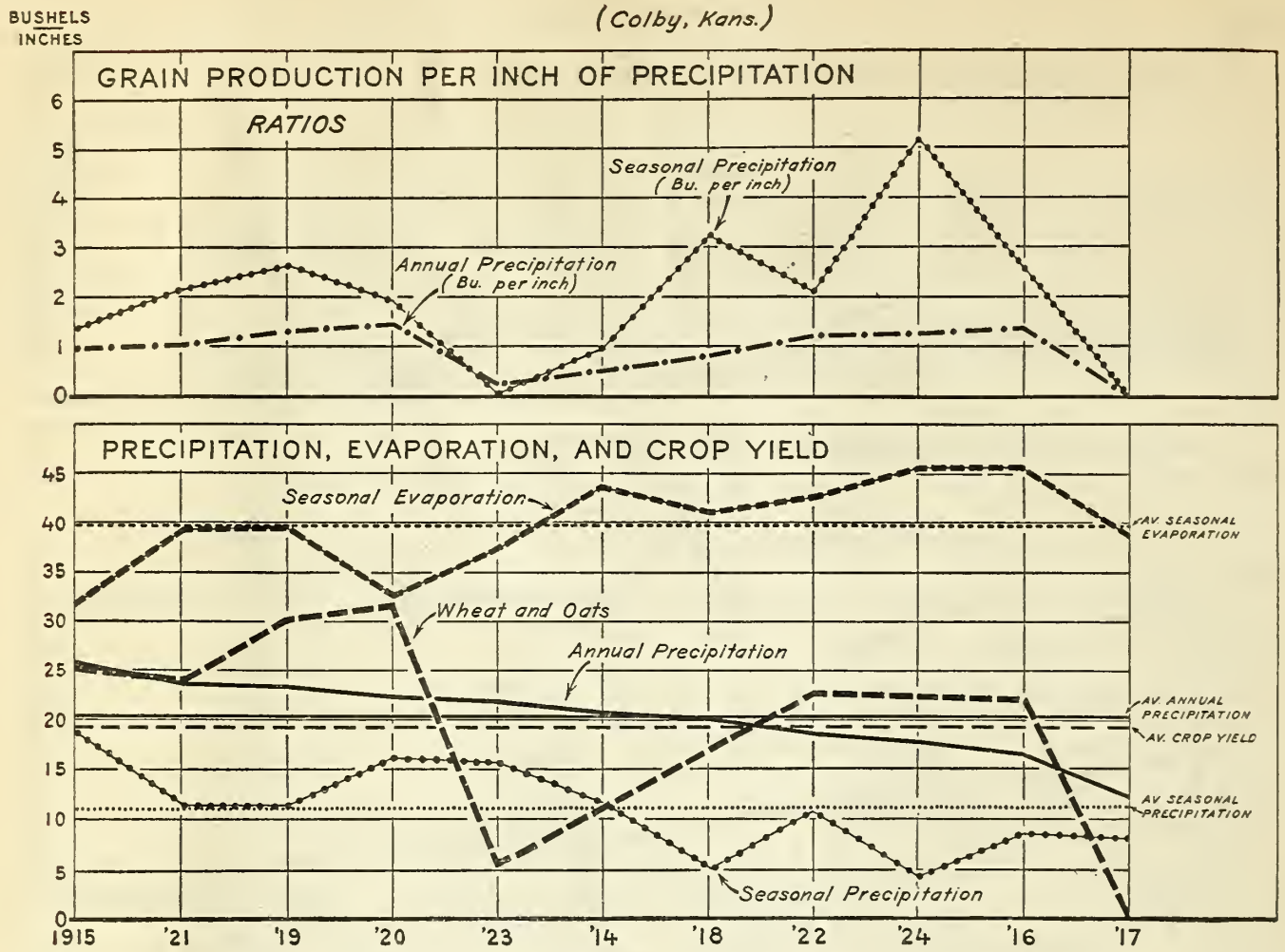


FIG. 63.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat only, 41; for a period of 11 years, at the Colby (Kans.) Field Station. (See Tables 7, 13, and 14)

plants, and the damage done by the parasites may be greater than the benefits of the favorable environment to the crop plants. The stage of growth of the crop plants when subjected to many of these inhibiting factors often determines the extent of the damage done. It is therefore generally very difficult to make any close estimate of the damage done by any single inhibiting factor, but it is believed that it is possible to make a rough estimate of the net effects of all inhibiting factors, as has been done in explaining the diagrams which follow those now under consideration.

It seems from the evidence of these diagrams that directly proportional relations never exist between annual precipitation and crop yields. Such relations are always thrown more or less out of equilibrium by inhibiting factors.

SUMMARY OF PRECIPITATION, CROP-YIELD, AND RATIO DATA

Figure 65 presents in graphic form a summary of the data contained in Figures 49 to 64, inclusive. In this figure the years are arranged in chronological sequence in accordance with Table 7, instead of in the order of magnitude of the annual precipitation. As only one station was reported in 1906 and only four stations in 1907, these years have not been included in this diagram. Each one of the fine lines in the lower portion of the diagram represents a single station. The heavy line marked "Average ratio" is the mean of all these lines. The figures upon which this diagram is based are presented in Table 7, with the stations they represent. The year 1908 presents but 6 stations, the years 1909, 1910, and 1911, 8 stations each; 1912, 10 stations; 1913, 11 stations; 1914 and 1915, 14 stations each; 1916, 15 stations; 1917 to 1920, inclusive, 16 stations each; 1921, 15 stations; 1922, 14 stations; 1923 and 1924, 13 stations each. The values of the several years, therefore, are not strictly comparable, but this difference in weight is not sufficient to affect materially the significant feature of the diagram, which is the intricate maze of lines representing the ratios between crop yields and annual precipitation owing to the absence of anything approaching proportional relations between these two factors. This fact is also demonstrated by the relations shown in the upper part of this figure by the lines representing crop yields and mean annual precipitation.

RELATIONS BETWEEN CROP YIELDS AND SEASONAL EVAPORATION AS COMPARED WITH ANNUAL PRECIPITATION

In order to show the relations between evaporation, crop yields, and precipitation Figure 66 is presented. The two lines representing crop yields and precipitation are the same as in Figure 65. That representing ratios is the "average ratio" shown in Figure 65, and the line representing evaporation has been inverted,

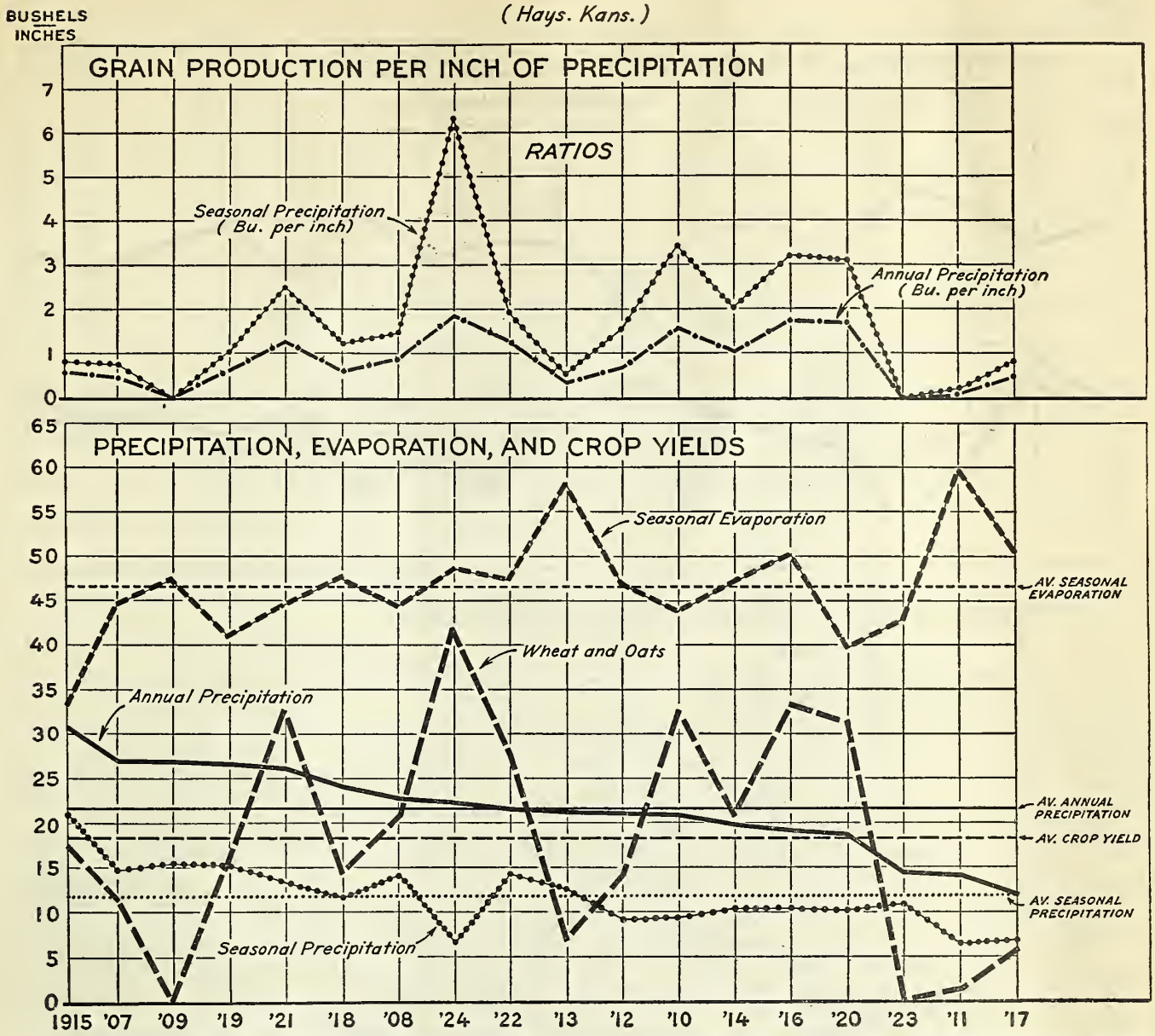


FIG. 64.—Diagram showing (lower portion) the composite yield of grain, in bushels per acre; seasonal and annual precipitation and seasonal evaporation, in inches; and (upper portion) the ratios of composite yields in bushels of grain to inches of precipitation, both seasonal and annual. Crops and number of plats used for each: Winter wheat only, 40; for a period of 18 years, at the Hays (Kans.) Field Station: (See Tables, 7, 13, and 14)

so as to show more clearly the inverse relations between evaporation and crop yields. These relations seem to be somewhat closer than those between crop yields and annual precipitation except for the year 1923, when some inhibiting factors seem to have intervened and reversed the normal relations. Although the subject of evaporation and its relation to crop yield undoubtedly deserves further study, it seems very doubtful whether such consideration will develop anything that will contravene the rule that the inhibiting factors usually dominate crop yields.

REDUCTION OF YIELDS DUE TO FACTORS OTHER THAN DEFICIENT ANNUAL PRECIPITATION

If it were possible to eliminate completely all of the adverse factors that inhibit the full realization of the crop-producing capacity of the soil with optimum conditions of temperature, moisture, and physical conditions for even a single year at each of the field stations, the crops produced under such ideal conditions would provide a standard by which it would be possible to calculate the reduction of crop yields due to factors other than deficient annual precipitation. It is, of course, useless to hope ever to realize any such conditions; for, in the first place, the forces of nature never have been and probably never will be completely under the control of man. In the second place, man is woefully ignorant of what constitutes such optimum conditions and would not know what conditions to provide for each crop during all of the stages of its growth and maturity even if he had the power to do so. But nature does occasionally provide conditions under which crops are produced that are so much superior to the average that they may be used as a standard of comparison for such average crops. The year 1915 was such a year at 8 of the 16 stations—Huntley, Archer, Scottsbluff, Bellefourche, Dickinson, Edgeley, Moccasin, and Akron. The year 1924 was such at North Platte and Hays, 1918 at Sheridan and Ardmore, 1916 at Assinniboine, 1909 at Williston, 1914 at Man-

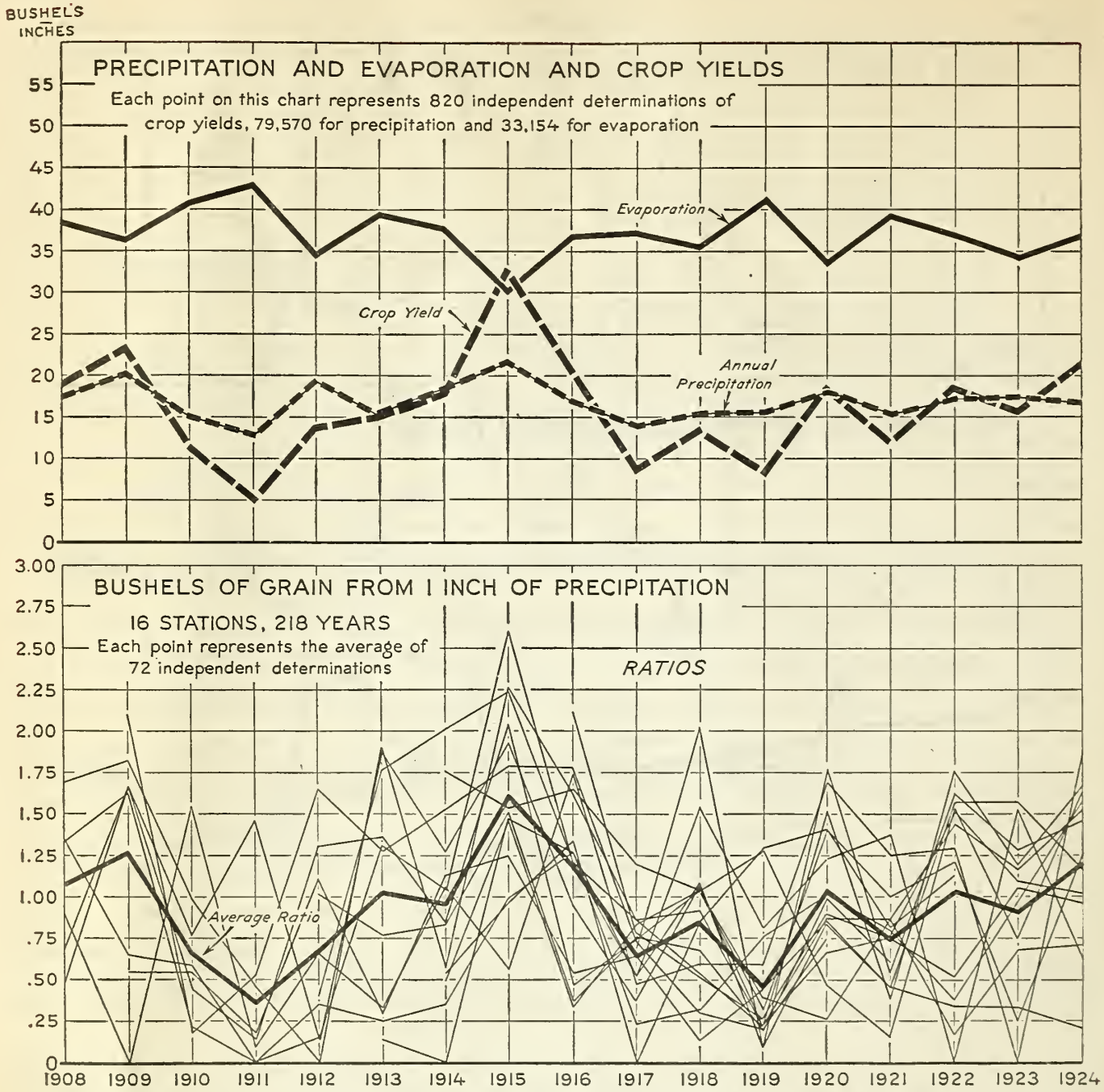


FIG. 65.—Diagram relating to 16 field stations in the northern Great Plains area for a period of 17 years, showing (lower portion) ratios of bushels of grain to inches of annual precipitation for each year at each field station, and the average of the ratios for all the stations for each year; and (upper portion) the means of the annual precipitation, and the seasonal evaporation, in inches, and the composite crop yields, in bushels per acre, for each year. (See Tables 7, 13, and 14)

dan, and 1920 at Colby. The yields produced at these stations and the ratios of bushels of grain to 1 inch of annual precipitation are given in Table 15.

The data presented in Table 15 are arranged as follows:

In section 1 is given the year showing the highest ratio of yields to precipitation for each station with the figures representing the yields in bushels, the ratios of grain in bushels to inches of rainfall, and the annual precipitation for that year in inches.

In section 2 are given the same data concerning yields, ratios, and precipitation, but the year for each station is that showing the highest annual precipitation, instead of the highest ratio, as in section 1.

In section 3 the results presented are those for years showing the highest yields, respectively, for each station.

Some very interesting and instructive facts are brought out by this presentation. Among them are the following:

(1) In 14 instances out of 16 the years giving the highest ratio were not the years of highest precipitation.

(2) In 5 instances out of 16 the years having the highest ratio were not the years of highest yields.

(3) In 11 instances out of 16 the years having the highest precipitation were not the years of highest yields.

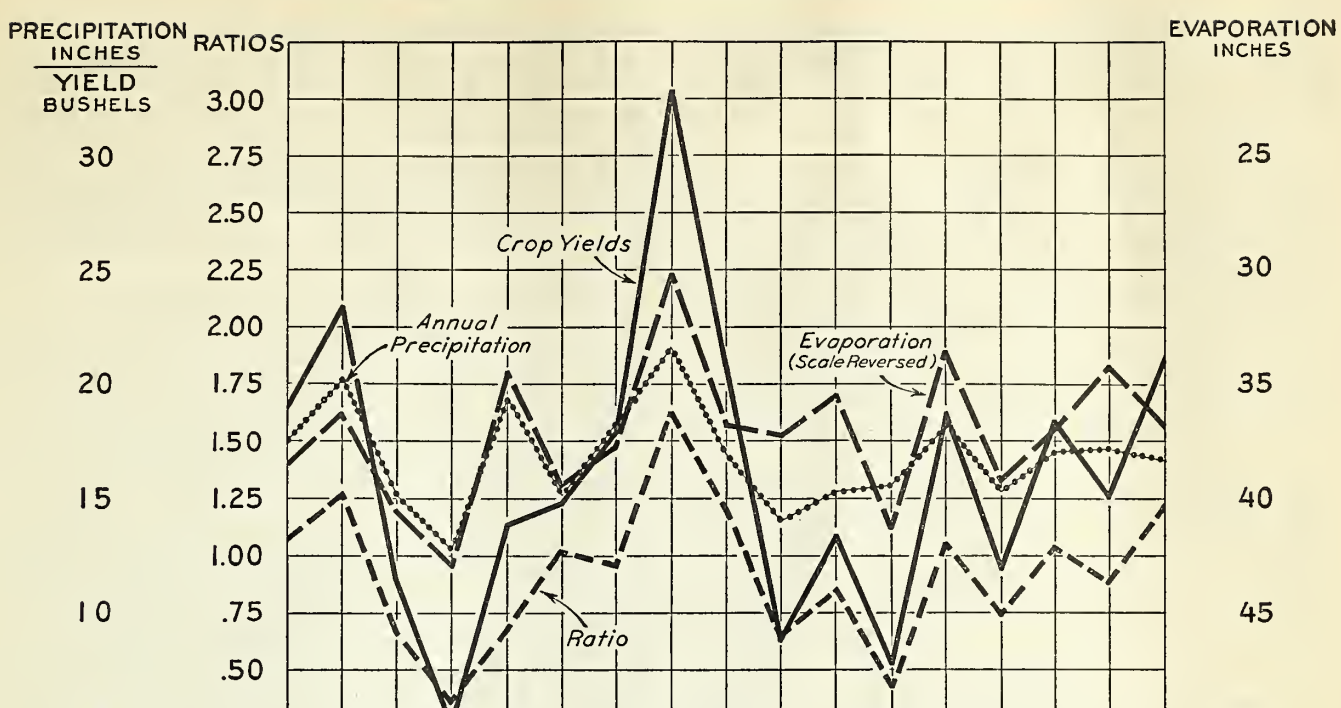


FIG. 66.—Diagram showing the relations of the means of crop yields, and ratios to annual precipitation and seasonal evaporation (reversed) for a period of 17 years at 16 field stations in the northern Great Plains. (See Tables 7 and 13)

Many other similar comparisons can be made from the figures given in Table 15, demonstrating that directly proportional relationships do not exist between crop yields and annual precipitation.

TABLE 15.—*Comparisons of crop yields, ratios, and annual precipitations, by groups of the years showing the highest values for each of these factors, at 16 field stations in the northern Great Plains area*

Field stations	Section 1.—Years of highest ratios				Section 2.—Years of highest precipitation				Section 3.—Years of highest yields			
	Year	Yields (bushels)	Ratios	Precipitation (inches)	Year	Yields (bushels)	Ratios	Precipitation (inches)	Year	Yields (bushels)	Ratios	Precipitation (inches)
Assinniboine	1916	45.0	2.25	20.01	1916	45.0	2.25	20.01	1916	45.0	2.25	20.01
Williston	1909	30.9	2.10	14.72	1914	32.2	1.53	21.00	1912	33.4	1.65	20.29
Huntley	1915	38.2	2.24	17.08	1920	17.8	.87	20.51	1915	38.2	2.24	17.08
Sheridan	1918	29.2	2.02	14.48	1924	31.0	1.46	21.25	1924	31.0	1.46	21.25
Archer	1915	22.6	1.46	15.50	1920	5.4	.26	20.86	1915	22.6	1.46	15.50
Scottsbluff	1915	23.8	1.51	15.78	1920	15.7	.85	18.44	1915	23.8	1.51	15.78
Bellefourche	1915	54.9	2.60	21.14	1920	23.8	.85	28.08	1915	54.9	2.60	21.14
Mandan	1914	41.9	1.76	23.79	1915	36.6	1.53	23.97	1914	41.9	1.76	23.79
Dickinson	1915	43.4	2.26	19.21	1914	13.3	.57	23.51	1915	43.4	2.28	19.21
Ardmore	1918	29.9	1.54	19.42	1915	39.3	1.47	26.82	1915	39.3	1.47	26.82
Edgeley	1915	38.6	2.04	18.94	1914	20.7	.84	24.67	1915	38.6	2.04	18.94
Moccasin	1915	34.6	1.93	17.94	1912	3.2	.14	22.31	1909	37.1	1.67	22.18
Akron	1915	28.4	1.25	22.81	1915	28.4	1.25	22.81	1915	28.4	1.25	22.81
North Platte	1924	27.0	1.57	17.18	1915	33.0	.99	33.33	1915	33.0	.99	33.33
Colby	1920	31.5	1.41	22.39	1915	25.1	.97	25.84	1920	31.5	1.41	22.39
Hays	1924	41.7	1.86	22.38	1915	17.2	.56	30.53	1924	41.7	1.86	22.38
Average	------	35.1	1.86	18.92	------	24.2	1.02	24.00	------	36.5	1.74	21.43
Mean average [1]	------	16.1	.93	16.54	------	16.1	.93	16.54	------	16.1	.93	16.54
Difference	------	19.0	.93	2.38	------	8.1	.09	7.46	------	20.4	.81	4.89

[1] See Table 7.

ESTIMATING THE MAGNITUDE OF INHIBITING FACTORS

As these investigations have progressed, and especially since this publication has been in preparation, the importance of inhibiting factors has become more apparent. Much time and effort have been devoted to the attempt to devise a method of making some kind of quantitative estimate of the relative magnitude of inhibiting factors in determining crop yields. Although it is known that these inhibiting factors are always present, because their effects are always apparent, the causes themselves are so elusive that it is only recently that any method has been found that seemed to render any assistance in estimating quantitatively the potency of the inhibiting factors. It is only after long and patient investigation that a method has been developed. Its limitations are fully realized, and it is for the purpose of bringing the method to the attention of those competent to assist in its development that it is now presented.

In Table 15 use has been made of the highest ratios of bushels of grain per inch of annual precipitation as a measure of the crop-producing possibilities at the various field stations. These are well established facts. It is known beyond a reasonable doubt that these numbers of bushels of grain equivalent to bushels of wheat have been produced from each inch of annual precipitation occurring at the respective stations. There is nothing theoretical about it. It has been done, not alone on a single plat but by replications ranging from 40 to 100.

The mean average annual precipitation has been established by meteorological observations made at each station for periods ranging from 8 to 18 years and averaging between 13 and 14 years. Although these means would be more reliable if they covered a longer period of time, they are unquestionably more trustworthy for this purpose than any other data now available.

The crop yields have been observed for the same length of time and at the same place where the meteorological observations have been made.

Three well-established groups of facts are therefore available: (1) The mean average crop yields, (2) the mean average annual precipitation, (3) and the ratios between these two, at 16 field stations on the northern Great Plains.

If, now, the mean annual precipitation for each one of these field stations is multiplied by the respective highest ratio of bushels of grain per inch of annual precipitation for each one of these field stations, it will furnish a fairly trustworthy basis for noting the actual mean yields that have been obtained and comparing them with the mean yields that might be produced at these stations, respectively, if the inhibiting factors were on an average no more potent than they have been on one or more years in the past. These computations have been made, and they are presented in Table 16.

TABLE 16.—*Comparison between calculated composite yields and mean yields actually obtained, showing the reduction due to inhibiting factors, at each of 16 field stations in the northern Great Plains area*

[Composite yields are calculated by multiplying the mean annual precipitations by the highest yield ratios obtained]

Field station	Mean annual precipitation	Average acre yields (bushels)			
		Highest ratio obtained	Calculated	Obtained	Reduction due to inhibiting factors
	Inches				
Assinniboine	12.36	2.25	27.8	12.1	15.7
Williston	14.68	2.10	30.8	17.0	13.8
Huntley	14.76	2.24	33.1	18.2	14.9
Sheridan	14.79	2.02	29.9	18.8	11.1
Archer	14.81	1.46	21.6	9.6	12.0
Scottsbluff	15.06	1.51	22.7	11.7	11.0
Bellefourche	15.80	2.60	41.1	16.9	24.2
Mandan	15.88	1.76	28.0	19.1	8.9
Dickinson	16.05	2.26	36.3	19.6	16.7
Ardmore	16.69	1.54	25.7	16.3	9.4
Edgeley	17.01	2.04	34.7	17.2	17.5
Moccasin	17.11	1.93	33.0	17.5	15.5
Akron	17.81	1.25	22.3	10.8	11.5
North Platte	20.02	1.57	31.4	14.7	16.7
Colby	20.29	1.41	28.6	19.2	9.4
Hays	21.59	1.86	40.2	18.2	22.0
Average	16.54	1.86	30.5	16.1	14.4

It is found that the actual mean yields for the stations fall short of the calculated yields by differences ranging from 8.9 to 24.2 bushels per acre, and averaging 14.4 bushels per acre for all stations. It is believed that 14.4 bushels per acre represents approximately the average annual effects of inhibiting factors throughout the entire period of the investigations for all stations; and that the figures in the right-hand column of the table represent, approximately, the average reduction in yields owing to inhibiting factors for each station, respectively.

It must be kept in mind that "the highest ratios obtained" may be, and probably are in many instances, considerably below the ratios that may be obtained in the future if these investigations are continued. Ratios of more than 2 bushels of grain per inch of annual precipitation have been obtained at 7 of the 16 stations. These 7 stations average a mean annual precipitation of 15.06 inches, which is 1.48 inches below the mean. Their ratios average 2.21 bushels of grain per inch of annual precipitation, which is 0.35 above the average of the highest ratios for all stations (1.86). The mean of the annual precipitation of the years when these highest ratios were obtained is 17.94 inches. This is only 1.40 inches above the mean for all stations for all years (16.54 inches); and all of the stations except Scottsbluff have exceeded this annual precipitation of 17.94 inches by from 2 to 15 inches in some years since the investigations began. There seems, therefore, to be no reason for supposing that ratios as high as any of those reported in Table 16, or higher than they are, may not be reached at any or all of these stations. It is simply a question of time when a season may occur at any of these stations when conditions are so favorable, or when inhibiting factors are so impotent, that ratios of 2.21 or higher may be attained at all stations.

If the inhibiting factors other than deficient annual precipitation could be held in abeyance to the same extent at all of the stations that they have been at seven of them, the average yields would be 36.55 bushels per acre, or more than twice what they have been on an average at all these stations during the period of these investigations. As a matter of fact, the average of the highest yields actually produced at all the stations is 36.5 bushels of grain per acre, as shown in Table 15. It therefore becomes obvious that crop yields on the Great Plains are determined by inhibiting factors other than deficient annual precipitation and that such inhibiting factors, on an average for all stations, have reduced the yields from 30.5 to 16.1 bushels, or 47 per cent, while for some stations this reduction has been over 50 per cent. These calculations are made upon different degrees of inhibition less than total destruction of a crop. It is obvious that when a crop is totally destroyed, as by hail, the potency of the inhibiting factor is 100 per cent. The lowest percentage given in Table 16 is 32. It may therefore be stated that, so far as our investigations show, the potency of the inhibiting factors ranges from 32 to 100 per cent.

Attention is again called to the fact that all of this comment concerning Table 16 is based upon differences in degrees of inhibition of crop production by factors other than deficient annual precipitation. If it were possible to eliminate entirely the inhibiting factors in a single instance, at each station, the resulting yields would afford a standard of comparison that would show much more impressively the dominating effects of the inhibiting factors upon crop yields. But the evidence contained in this table is sufficient to show that these inhibiting factors in many instances are the dominant factors.

Table 17 contains a rearrangement of some of the data given in Table 7, but so grouped as to facilitate the comparison of the composite yields obtained from the same crops grown on the same soils under the same methods of rotation and tillage, at the same stations and with annual precipitation the same to within 0.50 inch per annum. Opportunity is thus afforded to make 77 direct comparisons of yields with annual precipitation. The ratios of bushels of grain produced for each inch of annual precipitation and their deviations are also given. The years during which these similar precipitations occurred are not designated in Table 17, but can be found in Table 18.

In columns 2 and 3 the annual precipitations differing by not more than half an inch for each station are given. The higher precipitation is always given in column 2 and the lower in column 3. The corresponding yields are given in the same order in columns 5 and 6 and the ratios in columns 9 and 10. The yields corresponding to the precipitations given in column 2 are in column 5 and the ratios in column 9. The yields corresponding to the precipitations given in column 3 are in column 6 and the ratios in column 10. Deviations in precipitation are given by years in column 4; of yields by years

in column 7, and the average deviation in yields by stations in column 8; and the deviations in ratios by years are in column 11. The figures in column 12 refer to the numerical designation of the several crop years in Table 18 and Figure 67.

TABLE 17.—*Deviations of composite yields of small-grain crops as related to precipitation at 16 field stations in the northern Great Plains area, arranged in the order of magnitude of station precipitation*

Field stations	Annual precipitation (inches)			Corresponding crop yields (bushels)				Ratio of yield to rainfall			Key
				Deviation							
	Higher	Lower	Deviation	Cf. col. 2	Cf. col. 3	By years	By stations	Cf. cols 2 and 5	Cf. cols. 3 and 6	Deviation	
1	2	3	4	5	6	7	8	9	10	11	12
Assinniboine	10.80	10.78	0.02	5.4	9.6	4.2	4.95	0.50	0.89	0.39	5
	12.38	11.98	.40	11.9	6.2	5.7		.96	.52	.44	10
Williston	14.72	14.58	.14	30.9	11.0	19.9	11.65	2.10	.75	1.35	22
	10.02	10.01	.01	1.8	5.2	3.4		.18	.52	.34	1
Huntley	18.56	18.20	.36	26.8	27.9	1.1	9.65	1.44	1.53	.09	53
	14.30	14.17	.13	28.7	14.0	14.7		2.01	.99	1.02	18
	14.17	14.15	.02	14.0	24.9	10.9		.99	1.76	.77	17
	14.15	14.06	.09	24.9	13.0	11.9		1.76	.92	.84	16
Sheridan	14.60	14.48	.12	25.9	29.2	3.3	3.30	1.77	2.02	.25	21
	11.59	11.25	.34	10.1	1.9	8.2	6.62	.87	.17	.70	7
Archer	11.77	11.59	.18	1.6	10.1	8.5		.14	.87	.73	8
	11.90	11.77	.13	3.9	1.6	2.3		.33	.14	.19	9
	14.80	14.68	.12	7.3	10.0	2.7		.49	.68	.19	23
	15.85	15.50	.35	11.2	22.6	11.4		.71	1.46	.75	34
Scottsbluff	15.82	15.78	.04	16.2	23.8	7.6	5.12	1.02	1.51	.49	33
	15.78	15.30	.48	23.8	11.7	12.1		1.51	.76	.75	32
	15.30	15.27	.03	11.7	11.7	0		.76	.77	.01	29
	15.27	15.09	.18	11.7	12.5	.8		.77	.83	.06	27
Bellefourche	21.14	20.76	.38	54.9	24.0	30.9	11.92	2.60	1.16	1.44	62
	20.76	20.55	.21	24.0	32.2	8.2		1.16	1.57	.41	60
	14.45	14.42	.03	14.0	15.6	1.6		.97	1.08	.11	20
	13.74	13.57	.17	7.1	2.0	5.1		.52	.15	.37	14
	13.57	13.52	.05	2.0	18.0	16.0		.15	1.33	1.18	13
	13.31	13.13	.18	6.1	15.8	9.7		.46	1.20	.74	12
Mandan	23.97	23.79	.18	36.6	41.9	5.3	13.32	1.53	1.76	.23	73
	15.99	15.68	.31	24.4	11.8	12.6		1.53	.75	.78	35
	15.68	15.47	.21	11.8	25.5	13.7		.75	1.65	.90	31
	14.83	14.70	.13	2.2	23.9	21.7		.15	1.63	1.48	24
Dickinson	19.21	19.13	.08	43.4	19.0	24.4	7.44	2.26	.99	1.27	59
	19.13	18.97	.16	19.0	34.6	15.6		.99	1.82	.83	58
	18.97	18.54	.43	34.6	30.1	4.5		1.82	1.62	.20	57
	16.55	16.32	.23	27.4	27.8	.4		1.66	1.70	.04	41
	12.71	12.55	.16	19.3	27.1	7.8		1.52	2.16	.64	11
	10.70	10.53	.17	4.9	5.7	.8		.46	.54	.08	3
	10.53	10.35	.18	5.7	2.3	3.4		.54	.22	.32	2
	10.70	10.35	.35	4.9	2.3	2.6		.46	.22	.24	4
Ardmore	18.52	18.24	.28	27.6	23.1	4.5	11.94	1.49	1.27	.22	52
	16.49	16.22	.27	25.2	13.1	12.1		1.53	.81	.72	39
	16.22	15.79	.43	13.1	0	13.1		.81	0	.81	37
	14.36	14.09	.27	0	19.3	19.3		.00	1.37	1.37	19
	14.09	13.94	.15	19.3	8.6	10.7		1.37	.62	.75	15
Edgeley	24.67	24.62	.05	20.7	31.9	11.2	10.07	.84	1.30	.46	75
	18.58	18.33	.25	30.8	14.8	16.0		1.66	.81	.85	54
	18.94	18.58	.36	38.6	30.8	7.8		2.04	1.66	.38	56
	17.12	16.72	.40	19.3	27.9	8.6		1.13	1.67	.54	44
	16.13	15.63	.50	11.1	21.1	10.0		.69	1.35	.66	36
	11.24	11.16	.08	11.7	4.9	6.8		1.04	.44	.60	6
Akron	22.31	22.18	.13	3.2	37.1	33.9	6.89	.14	1.67	1.53	68
	18.83	18.33	.50	17.8	19.9	2.1		.95	1.09	.14	55
	17.02	16.78	.24	24.9	21.8	3.1		1.46	1.30	.16	43
	18.09	17.94	.15	19.3	34.6	15.3		1.07	1.93	.86	49
Moccasin	17.94	17.88	.06	34.6	6.6	28.0	13.44	1.93	.37	1.56	48
	18.11	18.09	.02	13.9	19.3	5.4		.77	1.07	.30	50
	15.41	15.28	.13	23.2	28.8	5.6		1.51	1.88	.37	30
	15.28	14.99	.29	28.8	7.2	21.6		1.88	.48	1.40	28
	18.33	18.11	.22	19.9	13.9	6.0		1.09	.77	.32	51
Akron	22.81	22.48	.33	28.4	19.3	9.1	6.89	1.25	.86	.39	72
	22.48	21.99	.49	19.3	9.6	9.7		.86	.44	.42	70
	21.99	21.62	.37	9.6	23.9	14.3		.44	1.11	.67	67
	21.62	21.36	.26	23.9	11.8	12.1		1.11	.55	.56	66
	17.12	16.86	.26	9.2	5.5	3.7		.54	.33	.21	45
	16.86	16.84	.02	5.5	5.8	.3		.33	.34	.01	42
	14.97	14.94	.03	6.9	4.5	2.4		.46	.30	.16	26
	14.94	14.83	.11	4.5	8.0	3.5		.30	.54	.24	25
North Platte	24.59	24.48	.11	18.8	23.8	5.0	4.62	.76	.97	.21	74
	21.62	21.58	.04	29.2	22.1	7.1		1.35	1.02	.33	65
	16.49	16.27	.22	3.8	5.7	1.9		.23	.35	.12	40
	17.88	17.75	.13	4.4	5.6	1.2		.25	.32	.07	47
	17.18	17.07	.11	27.0	21.6	5.4		1.57	1.27	.30	46
Colby	16.27	15.92	.35	5.7	12.8	7.1	26.00	.35	.80	.45	38
	22.39	21.96	.43	31.5	5.5	26.0		1.41	.25	1.16	69
	27.00	26.81	.19	11.7	0	11.7		.43	0	.43	77
	26.81	26.53	.28	0	15.7	15.7		.00	.59	.59	76
Hays	22.79	22.38	.41	20.6	41.7	21.1	15.73	.90	1.86	.96	71
	21.52	21.30	.22	27.6	7.1	20.5		1.28	.33	.95	64
	21.30	20.95	.35	7.1	14.5	7.4		.33	.69	.36	63
	20.95	20.92	.03	14.5	32.5	18.0		.69	1.55	.86	61
Average	17.08	16.87	.21	17.17	16.73	9.84	10.17	.988	.974	.572	
Mean average	16.97			16.95				0.981			

TABLE 18.—*Deviations of composite yields of small-grain crops as related to precipitation at 16 field stations in the northern Great Plains area, arranged in the order of annual precipitation for use as a key to Figure 67*

Key No.	Field stations	Annual precipitation (inches)				Corresponding crop yields (bushels)			Ratio of yield to rainfall		
		Pair of years	Higher	Lower	Deviation	Cf. col. 2	Cf. col. 3	Deviation by years	Cf. cols. 2 and 5	Cf. cols. 3 and 6	Deviation
	1	1a	2	3	4	5	6	7	9	10	11
1	Williston	1910, 1911	10.02	10.01	0.01	1.8	5.2	3.4	0.18	0.52	0.34
2	Dickinson	1918, 1919	10.53	10.35	.18	5.7	2.3	3.4	.54	.22	.32
3	do	1911, 1918	10.70	10.53	.17	4.9	5.7	.8	.46	.54	.08
4	do	1911, 1919	10.70	10.35	.35	4.9	2.3	2.6	.46	.22	.24
5	Assinniboine	1922, 1920	10.80	10.78	.02	5.4	9.6	4.2	.50	.89	.39
6	Edgeley	1918, 1910	11.24	11.16	.08	11.7	4.9	6.8	1.04	.44	.60
7	Archer	1921, 1922	11.59	11.25	.34	10.1	1.9	8.2	.87	.17	.70
8	do	1919, 1921	11.77	11.59	.18	1.6	10.1	8.5	.14	.87	.73
9	do	1916, 1919	11.90	11.77	.13	3.9	1.6	2.3	.33	.14	.19
10	Assinniboine	1924, 1918	12.38	11.98	.40	11.9	6.2	5.7	.96	.52	.44
11	Dickinson	1920, 1913	12.71	12.55	.16	19.3	27.1	7.8	1.52	2.16	.64
12	Bellefourche	1921, 1916	13.31	13.13	.18	6.1	15.8	9.7	.46	1.20	.74
13	do	1912, 1908	13.57	13.52	.05	2.0	18.0	16.0	.15	1.33	1.18
14	do	1917, 1912	13.74	13.57	.17	7.1	2.0	5.1	.52	.15	.37
15	Ardmore	1921, 1924	14.09	13.94	.15	19.3	8.6	10.7	1.37	.62	.75
16	Huntley	1913, 1918	14.15	14.06	.09	24.9	13.0	11.9	1.76	.92	.84
17	do	1923, 1913	14.17	14.15	.02	14.0	24.9	10.9	.99	1.76	.77
18	do	1914, 1923	14.30	14.17	.13	28.7	14.0	14.7	2.01	.99	1.02
19	Ardmore	1914, 1921	14.36	14.09	.27	0	19.3	19.3	0	1.37	1.37
20	Bellefourche	1913, 1918	14.45	14.42	.03	14.0	15.6	1.6	.97	1.08	.11
21	Sheridan	1920, 1918	14.60	14.48	.12	25.9	29.2	3.3	1.77	2.02	.25
22	Williston	1909, 1920	14.72	14.58	.14	30.9	11.0	19.9	2.10	.75	1.35
23	Archer	1914, 1923	14.80	14.68	.12	7.3	10.0	2.7	.49	.68	.19
24	Mandan	1921, 1924	14.83	14.70	.13	2.2	23.9	21.7	.15	1.63	1.48
25	Akron	1913, 1916	14.94	14.83	.11	4.5	8.0	3.5	.30	.54	.24
26	do	1921, 1913	14.97	14.94	.03	6.9	4.5	2.4	.46	.30	.16
27	Scottsbluff	1913, 1914	15.27	15.09	.18	11.7	12.5	.8	.77	.83	.06
28	Moccasin	1913, 1908	15.28	14.99	.29	28.8	7.2	21.6	1.88	.48	1.40
29	Scottsbluff	1917, 1913	15.30	15.27	.03	11.7	11.7	0	.76	.77	.01
30	Moccasin	1922, 1913	15.41	15.28	.13	23.2	28.8	5.6	1.51	1.88	.37
31	Mandan	1923, 1916	15.68	15.47	.21	11.8	25.5	13.7	.75	1.65	.90
32	Scottsbluff	1915, 1917	15.78	15.30	.48	23.8	11.7	12.1	1.51	.76	.75
33	do	1912, 1915	15.82	15.78	.04	16.2	23.8	7.6	1.02	1.51	.49
34	Archer	1924, 1915	15.85	15.50	.35	11.2	22.6	11.4	.71	1.46	.75
35	Mandan	1922, 1923	15.99	15.68	.31	24.4	11.8	12.6	1.53	.75	.78
36	Edgeley	1908, 1913	16.13	15.63	.50	11.1	21.1	10.0	.69	1.35	.66
37	Ardmore	1919, 1922	16.22	15.79	.43	13.1	0	13.1	.81	0	.81
38	North Platte	1914, 1921	16.27	15.92	.35	5.7	12.8	7.1	.35	.80	.45
39	Ardmore	1923, 1919	16.49	16.22	.27	25.2	13.1	12.1	1.53	.81	.72
40	North Platte	1917, 1914	16.49	16.27	.22	3.8	5.7	1.9	.23	.35	.12
41	Dickinson	1924, 1908	16.55	16.32	.23	27.4	27.8	.4	1.66	1.70	.04
42	Akron	1923, 1922	16.86	16.84	.02	5.5	5.8	.3	.33	.34	.01
43	Moccasin	1911, 1914	17.02	16.78	.24	24.9	21.8	3.1	1.46	1.30	.16
44	Edgeley	1922, 1909	17.12	16.72	.40	19.3	27.9	8.6	1.13	1.67	.54
45	Akron	1910, 1923	17.12	16.86	.26	9.2	5.5	3.7	.54	.33	.21
46	North Platte	1924, 1916	17.18	17.07	.11	27.0	21.6	5.4	1.57	1.27	.30
47	do	1913, 1918	17.88	17.75	.13	4.4	5.6	1.2	.25	.32	.07
48	Moccasin	1915, 1917	17.94	17.88	.06	34.6	6.6	28.0	1.93	.37	1.56
49	do	1918, 1915	18.09	17.94	.15	19.3	34.6	15.3	1.07	1.93	.86
50	do	1910, 1918	18.11	18.09	.02	13.9	19.3	5.4	.77	1.07	.30
51	do	1923, 1910	18.33	18.11	.22	19.9	13.9	6.0	1.09	.77	.32
52	Ardmore	1920, 1916	18.52	18.24	.28	27.6	23.1	4.5	1.49	1.27	.22
53	Huntley	1922, 1924	18.56	18.20	.36	26.8	27.9	1.1	1.44	1.53	.09
54	Edgeley	1906, 1921	18.58	18.33	.25	30.8	14.8	16.0	1.66	.81	.85
55	Moccasin	1916, 1923	18.83	18.33	.50	17.8	19.9	2.1	.95	1.09	.14
56	Edgeley	1915, 1906	18.94	18.58	.36	38.6	30.8	7.8	2.04	1.66	.38
57	Dickinson	1909, 1916	18.97	18.54	.43	34.6	30.1	4.5	1.82	1.62	.20
58	do	1910, 1909	19.13	18.97	.16	19.0	34.6	15.6	.99	1.82	.83
59	do	1915, 1910	19.21	19.13	.08	43.4	19.0	24.4	2.26	.99	1.27
60	Bellefourche	1924, 1922	20.76	20.55	.21	24.0	32.2	8.2	1.16	1.57	.41
61	Hays	1912, 1910	20.95	20.92	.03	14.5	32.5	18.0	.69	1.55	.86
62	Bellefourche	1915, 1924	21.14	20.76	.38	54.9	24.0	30.9	2.60	1.16	1.44
63	Hays	1913, 1912	21.30	20.95	.35	7.1	14.5	7.4	.33	.69	.36
64	do	1922, 1913	21.52	21.30	.22	27.6	7.1	20.5	1.28	.33	.95
65	North Platte	1908, 1920	21.62	21.58	.04	29.2	22.1	7.1	1.35	1.02	.33
66	Akron	1912, 1909	21.62	21.36	.26	23.9	11.8	12.1	1.11	.55	.56
67	do	1919, 1912	21.99	21.62	.37	9.6	23.9	14.3	.44	1.11	.67
68	Moccasin	1912, 1909	22.31	22.18	.13	3.2	37.1	33.9	.14	1.67	1.53
69	Colby	1920, 1923	22.39	21.96	.43	31.5	5.5	26.0	1.41	.25	1.16
70	Akron	1920, 1919	22.48	21.99	.49	19.3	9.6	9.7	.86	.44	.42
71	Hays	1908, 1924	22.79	22.38	.41	20.6	41.7	21.1	.90	1.86	.96
72	Akron	1915, 1920	22.81	22.48	.33	28.4	19.3	9.1	1.25	.86	.39
73	Mandan	1915, 1914	23.97	23.79	.18	36.6	41.9	5.3	1.53	1.76	.23
74	North Platte	1919, 1923	24.59	24.48	.11	18.8	23.8	5.0	.76	.97	.21
75	Edgeley	1914, 1912	24.67	24.62	.05	20.7	31.9	11.2	.84	1.30	.46
76	Hays	1909, 1919	26.81	26.53	.28	0	15.7	15.7	.00	.59	.59
77	do	1907, 1909	27.00	26.81	.19	11.7	0	11.7	.43	0	.43
	Average		17.08	16.87	.21	17.17	16.73	9.84	.988	.974	.572
	Mean average		16.97			16.95			0.981		

Table 18 contains the same data as Table 17, but so arranged as to serve as a key to Figure 67. In Table 18 there is no grouping by stations, as has been done in the other tables; but each pair of years is arranged in the order of magnitude of the annual precipitation, to correspond with the graphical arrangement of these data in

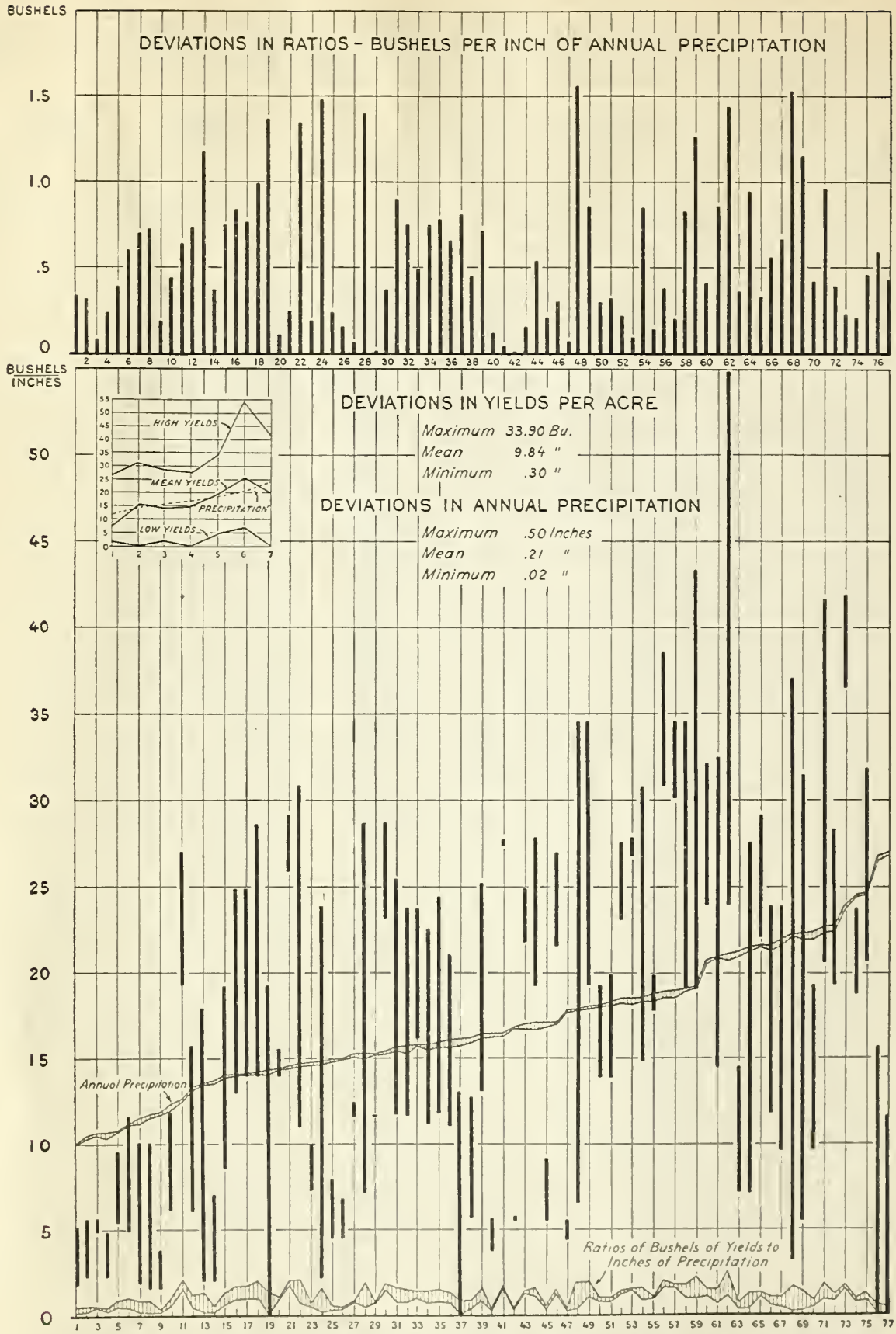


FIG. 67.—Diagram showing the deviations in composite crop yield and ratios in 77 instances where the difference in annual precipitation, in two different years, was less than one-half inch at the same station, with the same crops, the same soil, the same tillage methods, and the same crop sequence; at 16 field stations in the northern Great Plains. (See Tables 17 and 18)

Figure 67. In Table 18 the numbers from 1 to 77, inclusive, which are used to indicate the pairs of years, are found in the first column, while in Figure 67 the even-numbered designations are found extending from left to right across near the top of the page, and the odd numbers in like manner appear near the bottom.

There are a number of facts concerning Table 17 that make it of more value than is perhaps apparent. Although it presents the results of only 129 crop years, it embodies facts that are as representative of conditions as those contained in other tables dealing with the results of 218 or 303 years. It contains the data for all the crop years at the 16 northern field stations where there were one or more pairs of years having annual precipitations differing by less than one-half inch. The range in annual precipitation is from 10.01 to 27 inches. The yields are from 0 to 54.9 bushels per acre. The average annual precipitation for all crop years used is 16.97 inches, whereas the average for 218 crop years is 16.54, a difference of only 0.43 inch. The average yields are 16.95 bushels per acre as compared with 16.10 bushels, a difference of 0.85 bushel. Although the average deviation in annual precipitation is only 0.21 inch, the average deviation in crop yields regardless of station grouping is 9.84 bushels per acre, ranging from 0 to 33.9 bushels.

There is, of course, a rather wide range of average deviations for the several stations as compared with one another, but there is also a wide range in the number of crop years available for comparison. The lowest deviation for any station is 3.3 bushels at Sheridan, and the highest 26 bushels at Colby. Data are available for but one comparison at either of these stations. The largest number of comparisons is 9, at Moccasin, and the average deviation for this station is 13.44 bushels per acre. The mean of the average deviations of the 16 stations is 10.17 bushels.

The figures in column 12, at the extreme right of the table, headed "Key," refer to the numerical designations of the several crop years in Figure 67 and in Table 18.

Figure 67 is self-explanatory, but attention is called to the following significant features:

It will be noted that the ratios of bushels of grain to inches of annual precipitation shown by the approximately parallel lines running across the lower portion of the diagram show no continuing trend beyond the first ten. In other words, the average number of bushels of grain produced per inch of annual precipitation was practically the same whether the annual precipitation was 12 or 27 inches.

The main portion of the diagram is devoted to comparisons of yields and annual precipitation, and shows some remarkable differences in yields without any corresponding differences in annual precipitation; the maximum deviation in crop yields being 33.90 bushels, the mean 9.84 bushels, and the minimum 0.30; whereas the maximum deviation in annual precipitation was 0.50 inch per annum, the mean 0.21, and the minimum 0.02 inch.

The deviation in ratios between the same plats with the same crops, the same sequence and tillage methods, and with within one-half inch of the same annual precipitation, in different years, as shown in the upper portion of the diagram, shows the same general degree of departure throughout the entire range from 10 to 27 inches of annual precipitation.

The data representing crop yields in the main diagram are based upon the averages of 75 plats for each station year, and as two station years are represented by each of the 77 heavy vertical lines the total number of yields represented in the diagram is 75 by 77 by 2=11,550, which affords 77 comparisons of the average yields of groups of 75 plat yields. The distribution of yields as compared with annual precipitation in the figure is so erratic, considering the large number of plats involved, that it seemed desirable to concentrate the figures still further.

The 77 comparisons, therefore, were regrouped into 7 classes. The averages for these 7 classes, each representing 1,650 individual plat yields, are shown in the inset. Class 1, representing those plat years, has an average annual precipitation of 11.30 inches and an average yield of 7.18 bushels per acre; class 2, 14.13 inches annual precipitation and yields of 15.65 bushels; class 3, 15.28 inches and 14.35 bushels; class 4, 16.45 inches and 15.54 bushels; class 5, 18.10 inches and 19.28 bushels; class 6, 20.47 inches and 26.16 bushels; class 7, 23.80 inches and 20.49 bushels. The ratios of bushels of grain per inch of annual precipitation for these 7 classes, respectively, were as follows: 0.64, 1.11, 0.94, 0.94, 1.07, 1.28, and 0.86. The mean ratio for the entire series as shown in Table 17 is 0.98. If, now, we multiply the inches of annual precipitation for each of these 7 classes by 0.98 we get the following figures as the respective yields that would have been produced if the inhibiting factors had been normal for all 7 classes: 11.07, 13.85, 14.97, 16.12, 17.74, 20.06, 23.32. The differences between these calculated yields and those which were actually obtained give the following values for the inhibiting factors: −3.89, +1.80, −0.62, −0.58, +1.54, +6.10, and −2.83 bushels per acre thus showing the relative potency of inhibiting factors.

The lines in the inset marked "high yields" and "low yields" show in a striking way the range of the yields from which the mean yields are computed. This range far exceeds that of the difference in mean yields of the classes having the highest and the lowest annual precipitation. Further comment seems unnecessary.

SUMMARY AND RECOMMENDATIONS

This publication will make available to other investigators, and to the general public, some basic data heretofore unavailable. It is believed by the writer that these data may be more valuable than are the interpretations of them herein presented. It is hoped that they may be fully utilized.

At the present stage of these investigations the results seem to indicate certain outstanding features.

Notwithstanding the fact that annual precipitation is a vital factor in determining crop yield, it is seldom if ever the dominant factor; but the limitation of crop yield is most frequently due to the operation of one or of several inhibiting factors other than shortage of rainfall.

Yields equivalent to 10 bushels or less per acre of wheat have occurred in 75 of the 218 crop years during which these investigations have been conducted at 16 stations on the northern Great Plains. During 23 of these 75 years the annual precipitation was less than 12 inches. During the remaining 52 of the 75 crop years the low yields were due to inhibiting factors other than inadequate annual precipitation. But, nevertheless, the composite crop yields have averaged throughout the entire 218 crop years the equivalent of 16.1 bushels of wheat per acre.

The mean annual precipitation of the Great Plains as represented by the 23 dry-land field stations is sufficient to produce crops equivalent to those obtained at the 16 stations if the inhibiting factors are no more potent than they have been during the period covered by these investigations.

With respect to climatic conditions, no extensive portion of the Great Plains as represented by these field stations is markedly superior or inferior to any other portion; but the accumulated experience of practical farmers may, in the future, afford a basis for revising present-day estimates of relative agricultural possibilities.

It is highly desirable that the fullest possible knowledge be acquired concerning the climatic conditions of the Great Plains. Such information is indispensable to the farmers of this region when planning their cropping systems. Many of the inhibiting factors which limit crop yields are meteorological in character; and others, such as insects and diseases, are very susceptible to climatic conditions.

Although the United States Department of Agriculture and the State experiment stations can render important assistance and should continue to do so, the ultimate solution of the problems of crop production can be attained only by practical farmers.

The agricultural development should be slow, there being neither economic justification nor adequate knowledge to bring the Great Plains up to its full agricultural possibilities in the near future.

It will be impracticable to effect any detailed agricultural classification of the land in the semiarid portions of the Great Plains, based upon either meteorological data, native vegetation, or soil types, until a much more stable background of agricultural experience has been established.

The Great Plains area has been and should continue to be chiefly devoted to stock raising, and all agencies interested in the agricultural, social, and economic development of this vast region of more than 450,000 square miles should unite in bringing about conditions that will make possible the fullest development of its natural resources for stock production. Crop production should be aimed to supplement livestock production rather than to compete with it.

When sufficient experience has been acquired as to the crops and the farming practices best adapted to local conditions, the enterprise of pioneer farmers can be depended upon to develop the agriculture of the Great Plains as rapidly as is justified by economic conditions. No artificial stimulation of land settlement in this region is justified at the present time.

In its present state of agricultural development, land prices and local taxes in general are too high in proportion to the revenue-producing capacity of the region.

For the homeseeker with small capital and without practical agricultural experience on the Great Plains the chances of success are remote. But where practical experience and adequate capital combine, and when a real economic demand for increased agricultural production develops, the Great Plains of America are destined to become one of the world's greatest food-producing regions.

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